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SIGNIFICANCE OF THE ETHER-DRIFT EXPERIMENTS OF 1925 AT MOUNT WILSON[1]

THE general acceptance of the theory that light consists of wave motion in a luminiferous ether made it necessary to determine the essential properties of the ether which will enable it to transmit the waves of light and to account for optical phenomena in general. The ether was at first presumed to fill all space, even that occupied by material bodies, and yet to allow all bodies to move through it with apparent perfect freedom. The question of whether the ether is carried along by the earth's motion has been considered from the early days of the wave theory. Theories of the ether are intimately associated with theories of the structure of matter, and these are among the most fundamental in the whole domain of physical science.

The discovery of the aberration of light, in 1728, was soon followed by an explanation according to the then accepted corpuscular theory of light. The effect was attributed to a simple composition of the velocity of light with the velocity of the earth in its orbit. A second explanation was proposed, based on the wave theory, which seemed almost as simple as the former, but it failed to account for the fact, later proved by experiment, that the aberration is unchanged when observations are made with a telescope filled with water. Fresnel developed the theory which has been generally accepted, first, that the ether is at rest in free space and in opaque bodies, while, second, in the interior of moving transparent bodies it is supposed to move with a velocity less than the velocity of the body in the ratio $\frac{n^2-1}{n^2}$, where n is the index of refraction. These two hypotheses give a complete and satisfactory explanation of aberration; the second is considered to have been proved by the experiments of Fizeau and of Michelson and Morley on the velocity of light in moving media; the first hypothesis, that of an ether at rest in space and in opaque bodies, has always been in doubt.

Several physicists have sought to prove the existence of the stationary ether by direct experiment. The most fundamental of such proposals was that of Professor A. A. Michelson, made in 1881, based upon the idea that the ether as a whole is at rest and that light waves are propagated in the free ether in any direction and always with the same velocity with re-

[1] Address of the president of the American Physical Society, read at Kansas City, December 29, 1925.

spect to the ether. It was also assumed that the earth in its orbital motion around the sun passes freely through this ether as though the latter were absolutely stationary in space. The experiment proposed to detect a relative motion between the earth and the ether, and it is this relative motion which is often referred to as "ether-drift." The experiment is based upon the argument that the apparent velocity of light would vary according to whether the observer is carried by the earth in the line in which the light is traveling or at right angles to this line. The velocity of light is three hundred thousand kilometers per second, while the velocity of the earth in its orbit is one ten thousandth part of this, thirty kilometers per second. The actual motion of the earth is at all times the resultant of the motion of the earth in its orbit, varying in direction and having a velocity of thirty kilometers per second, and of the constant motion of the sun (including the whole solar system), in an unknown direction and with an unknown velocity. Therefore, the actual relative motion of the earth and ether is unknown, and it may be less than thirty kilometers per second or very much greater. If it is assumed that the relative motion is equal to that of the earth in its orbit, and if it were possible to measure the direct effect of this motion on the *apparent* velocity of light, then the velocity measured in the line of motion should differ from the apparent velocity at right angles to this line, by thirty kilometers per second, or by one part in ten thousand. This is what is called a "first order effect"; but, unfortunately, there is no known method of measuring the velocities under such simple conditions. All methods require the ray of light to travel to a distant station and back again to the starting point, and a positive effect of the earth's motion on the ray going outward would be neutralized by a negative effect on the returning ray. But, for a moving observer, it was shown that the neutralization would not be quite complete; the apparent velocity of the ray going and coming in the line of the earth's motion would differ from the apparent velocity of the ray going and coming at right angles, in the ratio of the square of the velocity of the earth to the velocity of light, that is, by an amount equal to one part in $(10{,}000)^2$ or to one part in 100,000,000. The only effect which can be experimentally determined, therefore, is exceedingly minute; it is a "second order effect."

A remarkable instrument known as the "interferometer," which had been invented by Professor Michelson, is capable of detecting a change in the velocity of light of the small amount involved in ether drift. In this experiment a beam of light is literally split in two by a thin film of silver, on what is called the "half-silvered mirror"; the coating of silver is thin enough to allow about half of the light to pass straight through, while the other half is reflected in the usual manner. These two beams of light may thus be made to travel paths at right angles to each other. At the end of the desired path each beam is reflected back upon itself and the two come together where they first separated. If the two paths are optically equal, that is, if there are exactly the same number of wave-lengths of light in each, the reunited portions will blend with the waves in concordance. If, however, one path is a half-wave longer than the other, the waves will come together in "opposite phase," the crest of one coinciding with the trough of the other. These and other phase relations between the two rays produce effects called "interference fringes," observation of which enables one to detect slight changes in the velocity of light in the two paths.

In the year 1887, at Case School of Applied Science, in Cleveland, Professor Michelson, in collaboration with the late Professor Edward W. Morley, of Western Reserve University, made certain important developments of method and apparatus and used the interferometer in the now famous "Michelson-Morley experiment," in an effort to determine whether the motion of the earth through space produces the effect upon the velocity of light as predicted by theory. Unfortunately we do not know in what absolute direction the earth is going and so it is not possible to place the interferometer certainly in this direction. Therefore, the whole apparatus is mounted on a base which floats on mercury so that it can be turned to all azimuths of the horizontal plane of observation in the effort to find the direction of the drift. The rotation of the earth on its axis causes the plane of the interferometer to move as though it were on the surface of a rotating cone, the axis of which coincides with that of the earth and thus to take many different space orientations. It is only that component of the actual drift which lies in the plane of the interferometer at the moment of observation which can be observed. Therefore, the apparent azimuth and magnitude of the drift should change with the time of observation.

The full significance of the ether-drift experiments of 1925 can be presented only by considering the interpretations given to the experiments made previously. For this reason a historical summary of all the experiments will be given.

In July, 1887, Michelson and Morley made six sets of observations for the ether-drift effect, one at noon and one at six o'clock in the evening, on each of three days, July 8, 9 and 11. This constitutes the whole of the observations made by Michelson and Morley. In November, 1887, they announced their conclusions as follows: "Considering the motion of the earth in its orbit only . . . the observations show that the relative motion of the earth and the ether is probably less

than one sixth of the earth's orbital velocity and certainly less than one fourth."[2] (That is, it is less than seven and one half kilometers per second.) It is to be noted that this experiment was designed and carried out solely to detect the influence of the earth's orbital motion, which should have different values at the two times of day chosen for observation, and that the smallest quantity which could be measured with certainty was one fourth of the expected effect.

In 1895, Lorentz and FitzGerald suggested that the motion of translation of a solid through the ether might produce a contraction in the direction of the motion, with extension transversely, the amount of which is proportional to the square of the ratio of the velocities of translation and of light, and which might have a magnitude such as to annul the effect of the ether-drift in the Michelson-Morley interferometer. The optical dimensions of this instrument were determined by the base of sandstone on which the mirrors were supported. If the contraction depends upon the physical properties of the solid, it was suggested that pine timber would suffer greater compression than sandstone, while steel might be compressed in a lesser degree. If the compression annuls the expected effect in one apparatus, it might in another apparatus give place to an effect other than zero, perhaps with the contrary sign.

The writer, in collaboration with Professor Morley, constructed an interferometer about four times as sensitive as the one used in the first experiment, having a light path of 214 feet, equal to about 130,000,000 wave-lengths. In this instrument a relative velocity of the earth and ether equal to the earth's orbital velocity would be indicated by a displacement of the interference fringes equal to 1.1 fringes. This is the size of the instrument which has been used ever since. The optical parts were all new and nothing was used from the original apparatus excepting the mercury tank and its wooden float.

Such an instrument with a base made of planks of pine wood was used at Cleveland, in 1902, 1903 and 1904, for the purpose of directly testing the Lorentz-FitzGerald effect, but the changes in the wooden frame due to the variations in humidity and temperature made it difficult to obtain accurate observations. A new supporting frame was designed by Professor F. H. Neff, of the Department of Civil Engineering of Case School of Applied Science, the purpose being to secure both symmetry and rigidity. This frame, or base, was made of structural steel and was so arranged that the optical dimensions could be made to depend upon distance-pieces of wood, or upon the steel frame itself. Observations were made with this apparatus in 1904. The procedure was based upon the effect to be expected from the combination of the diurnal and annual motions of the earth together with the presumed motion of the solar system towards the constellation *Hercules* with a velocity of 17.7 kilometers per second. On the dates chosen for the observations there were two times of the day when the resultant of these motions would lie in the plane of the interferometer, about 11:30 o'clock, A. M., and 9:00 o'clock, P. M. The calculated azimuths of the motion would be different for these two times. The observations at these two times were, therefore, combined in such a way that the presumed azimuth for the morning observations coincided with that for the evening. The observations for the two times of day gave results having positive magnitudes but having nearly opposite phases; when these were combined, the result was nearly zero. The result, therefore, was opposed to the theory then under consideration; but according to the ideas which will be set forth later in this address it now seems that the superposition of the two sets of observations of different phases was based upon an erroneous hypothesis and that the positive results then obtained are in accordance with a new hypothesis as to the solar motion. Our report of these experiments published in the *Philosophical Magazine* for May, 1905, concludes with the following statement: "Some have thought that this experiment only proves that the ether in a certain basement room is carried along with it. We desire therefore to place the apparatus on a hill to see if an effect can be there detected."[3]

In the autumn of 1905, Morley and Miller removed the interferometer from the laboratory basement to a site on Euclid Heights, Cleveland, free from obstruction by buildings, and having an altitude of about three hundred feet above Lake Erie and about eight hundred and seventy feet above sea-level. Five sets of observations were made in 1905–1906, which give a definite positive effect of about one tenth of the then "expected" drift. There was a suspicion that this might be due to a temperature effect, though there was no direct evidence of this. A plan was made for putting this surmise to the test after a summer's vacation. We had erected the interferometer on land owned by a friend; during our vacation absence, the land was sold and the new owner ordered the immediate removal of the interferometer. Professor Morley retired from active work in 1906 and it devolved upon the present writer to continue the experiments.

[2] Michelson and Morley, "Relative Motion of the Earth and the Luminiferous Ether," *Am. Jl. of Sci.*, 34, 333 (1887); *Phil. Mag.*, 24, 449 (1887); *Jl. de Phys.*, 7, 444 (1888).

[3] Morley and Miller, "An Experiment to detect the Fitz-Gerald-Lorentz Effect," *Phil. Mag.*, 9, 680 (1905); Proc. Am. Acad. Arts and Sci., 41, 321 (1905); "On the Theory of Experiments to detect Aberrations of the Second Degree," *Phil. Mag.*, 9, 669 (1905).

It seemed desirable that further observations should be carried out at a much higher altitude, but numerous causes prevented the resumption of observations.

It was at this time that Einstein became interested; and in November, 1905, he published a paper on "The Electrodynamics of Moving Bodies."[4] This paper was the first of a long series of papers and treatises by Einstein and others, which has developed into the present theory of relativity. In this first paper, Einstein states the principle of the constancy of the velocity of light, postulating that for an observer on the moving earth, the measured velocity of light must be constant, regardless of the direction or amount of the earth's motion. The whole theory was related to physical phenomena, largely on the assumption that the ether-drift experiments of Michelson, Morley and Miller had given a definite and exact null result.

The deflection of light from the stars by the sun, as predicted by the theory of relativity, was put to the test at the time of the solar eclipse of 1919. The results were widely accepted as confirming the theory. This revived the writer's interest in the ether-drift experiments, the interpretation of which had never been acceptable to him.

The site of the Mount Wilson Observatory, near Pasadena, California, at an elevation of about six thousand feet, appeared to be a suitable place for further trials. An elaborate program of experimentation was prepared, and ample funds to cover the very considerable expense involved were very generously provided by Mr. Eckstein Case, of Cleveland. The president and trustees of Case School of Applied Science gave every possible assistance by allowing leave of absence to the writer at such times as were desirable for making the experiments and by providing an assistant for carrying on the very laborious work of calculating and analyzing the observations. Through the kindness of President Merriam, of the Carnegie Institution of Washington, and of Directors Hale and Adams, the ether-drift experiments have been carried on at the Mount Wilson Observatory during the past five years.

Observations were begun in March, 1921, using the apparatus and methods employed by Morley and Miller in 1904, 1905 and 1906, with certain modifications and developments in details. The very first observation gave a positive effect such as would be produced by a real ether-drift, corresponding to a relative motion of the earth and ether of about ten kilometers per second. But before announcing such a result it seemed necessary to study every possible cause which might produce a displacement of fringes similar to that caused by ether-drift; among the causes suggested were magneto-striction and radiant heat. In order to test the latter the metal parts of the interferometer were completely covered with cork about one inch thick, and fifty sets of observations were made showing a periodic displacement of the fringes, as in the first observations, thus showing that radiant heat is not the cause of the observed effect.

In the summer of 1921 the steel frame of the interferometer was dismounted and a base of one piece of concrete, reinforced with brass, was cast in place on the mercury float. All the metal parts were made of aluminum or brass, thus the entire apparatus was free from magnetic effects and the possible effects due to heat were much reduced. In December, 1921, forty-two sets of observations were made with the non-magnetic interferometer. These show a positive effect as of an ether drift, which is entirely consistent with the observations of April, 1921. Many variations of incidental conditions were tried at this epoch. Observations were made with rotations of the interferometer clockwise and counter-clockwise, with a rapid rotation and a very slow rotation, with the interferometer extremely out of level, due to the loading of the float on one side. Many variations of procedure in observing and recording were tried. The results of the observations were not affected by any of these changes.[5]

The entire apparatus was returned to the laboratory in Cleveland. During the years 1922 and 1923 many trials were made under various conditions which could be controlled and with many modifications of the arrangements of parts in the apparatus. An arrangement of prisms and mirrors was made so that the source of light could be placed outside of the observing room, and a further complication of mirrors was tried for observing the fringes from a stationary telescope. Methods of photographic registration by means of a motion picture camera were tried. Various sources of light were employed, including sunlight and the electric arc. Finally an arrangement was perfected for making observations with an astronomical telescope having an objective of five inches aperture and a magnification of fifty diameters. The source of light adopted was a large acetylene lamp of the kind commonly used for automobile headlights. An extended series of experiments was made to determine the influence of inequality of temperature and of radiant heat, and various insulating covers were provided for the base of the interferometer and for the light path. These experiments proved that under the conditions of actual observation the periodic displacement could not possibly be produced by temperature effects. An ex-

[4] Einstein, "Zur electrodynamik bewegter Körper, *Ann. der Physik*, 17, 891 (1905).

[5] Miller, "Ether-drift Experiments at Mount Wilson Observatory," *Phys. Rev.*, 19, 407 (1922); SCIENCE, 55, 496 (1922).

tended investigation in the laboratory demonstrated that the full-period effect mentioned in the preliminary report of the Mount Wilson observations is a necessary geometrical consequence of the adjustment of mirrors when fringes of finite width are used and that the effect vanishes only for fringes of infinite width, as is presumed in the simple theory of the experiment.

In July, 1924, the interferometer was taken again to Mount Wilson and mounted on a new site where the temperature conditions were more favorable than those of 1921. The interferometer house was also mounted with a different orientation. Again the observations showed a real periodic displacement of the fringes, as in all the observations previously made at Mount Wilson and at Cleveland.

In spite of long-continued efforts it was impossible to account for these effects as being due to terrestrial causes or to experimental errors. Very extended calculations were made in the effort to reconcile the observed effects with the accepted theories of the ether and of the presumed motions of the earth in space. The observations were repeated at certain epochs to tests one after another of the hypotheses which were suggested. At the end of the year 1924, when a solution seemed impossible, a complete calculation of the then expected effects, for each month of the year, was made for the first time. This indicated that the effect should be a maximum about April first, and further that the direction of the effect should, in the course of the twenty-four hours of the day, rotate completely around the horizon. Observations were made for verifying these predictions in March and April, 1925. The effect was equal in magnitude to the largest so far observed; but it did not point successively to all points of the compass, that is, it did not point in directions 90° apart at intervals of six hours, nor point in opposite directions at intervals of twelve hours. Instead of this, the direction merely oscillated back and forth through an angle of about 60°, having, in general, a northwesterly direction.

Previous to 1925, the Michelson-Morley experiment has always been applied to test a specific hypothesis. The only theory of the ether which has been put to the test is that of the absolutely stationary ether through which the earth moves without in any way disturbing it. To this hypothesis the experiment gave a negative answer. The experiment was applied to test the question only in connection with specific assumed motions of the earth, namely, the axial and orbital motions combined with a constant motion of the solar system towards the constellation Hercules with the velocity of about nineteen kilometers per second. The results of the experiment did not agree with these presumed motions. The experiment was applied to test the Lorentz-FitzGerald hypothesis that the dimensions of bodies are changed by their motions through the ether; it was applied to test the effects of magneto-striction, of radiant heat and of gravitational deformation of the frame of the interferometer. Throughout all these observations, extending over a period of years, while the answers to the various questions have been "no," there has persisted a constant and consistent small effect which has not been explained.

The ether-drift interferometer is an instrument which is generally admitted to be suitable for determining the relative motion of the earth and the ether, that is, it is capable of indicating the direction and the magnitude of the absolute motion of the earth and the solar system in space. If observations were made for the determination of such an absolute motion, what would be the result, independent of any "expected" result? For the purpose of answering this general question, it was decided to make more extended observations at other epochs in 1925, and this was done in the months of July, August and September.

It may be asked: why was not such a procedure adopted before? The answer is, in part, that we were concerned with the verification of certain predictions of the so-called classical theories; and in part that it is not easy to develop a new hypothesis, however simple, in the absence of direct indication. Probably a considerable reason for the failure is the great difficulty involved in making the observations at all times of day at any one epoch. I think I am not egotistical, but am merely stating a fact when it is remarked that the ether-drift observations are the most trying and fatiguing, as regards physical, mental and nervous strain, of any scientific work with which I am acquainted. The mere adjustment of an interferometer for white-light fringes and the keeping of it in adjustment, when the light path is 214 feet, made up of sixteen different parts, and when it is in effect in the open air, requires patience as well as a steady "nerve" and a steady hand. Professor Morley once said, "Patience is a possession without which no one is likely to begin observation of this kind." The observations must be made in the dark; in the daytime, the interferometer house is darkened with black paper shades; the observations must be made in a temperature which is exactly that of the out-of-door air; the observer has to walk around a circle about twenty feet in diameter, keeping his eye at the moving eyepiece of the telescope attached to the interferometer which is floating on mercury and is turning on its axis steadily, at the rate of about one turn a minute; the observer must not touch the interferometer in any way, and yet he must never lose sight of the interference fringes, which are seen only through the small

aperture of the eyepiece of the telescope, about a quarter of an inch in diameter; the observer makes sixteen readings of the position of the interference fringes in each turn, at times indicated by an electrical clicker; these operations must be continued without a break through a set of observations, which usually lasts for about fifteen or twenty minutes, and this is repeated continuously during the several hours of the working period.

When observations are in progress the interferometer to which the observing telescope is attached is caused to rotate on the mercury float so that the telescope points successively to all points of the compass, that is, it points to all azimuths. A relative motion of the earth and the ether should cause a periodic displacement of the interference fringes, the fringes moving first to one side and then to the other as referred to a fiducial point in the field of view, with two complete periods in each rotation of the instrument. Beginning when the telescope points north, the position of the fringes is noted at sixteen equidistant points around the horizon. The azimuth of the line of sight when the displacement is a maximum having been noted at two different times of day, it is a simple operation to calculate the right ascension and declination, or the "apex" of the presumed "absolute" motion of the earth in space. The determination of the direction of the earth's motion is dependent only upon the direction in which the telescope points when the observed displacement of the fringes is a maximum; it is in no way dependent upon the amount of this displacement nor upon the adjustment of the fringes to any particular zero position. As the readings are taken at intervals of about three seconds, the position of the maximum is dependent upon observations covering an interval of less than ten seconds. A whole period of the displacement extends over only about twenty-five seconds. Thus the observations for the direction of the absolute motion are largely independent of ordinary temperature disturbances. The observation is a differential one and can be made with considerable certainty under all conditions. A set of readings usually consists of twenty turns of the interferometer made in about fifteen minutes' time; this gives forty determinations of the periodic effect. The forty values are simply averaged to give one "observation." Any temperature effect, or other disturbing cause, which is not regularly periodic in each twenty seconds over an interval of fifteen minutes would largely be cancelled out in the process of averaging. The periodic effect remaining in the final average must be real.

The position of the fringe system is noted in units of a tenth of a fringe width. The actual velocity of the earth's motion is determined by the amplitude of the periodic displacement, which is proportional to the square of the relative velocity of the earth and the ether and to the length of the light path in the interferometer. A relative motion of thirty kilometers per second, equal to the velocity of the earth in its orbit, would produce a displacement of the fringes from one extreme to the other, of 1.1 fringes. Disturbances due to temperature or other causes lasting for a few seconds or for a few minutes might affect the actual amount of the observed displacement and thus give less certain values for the velocity of relative motion, while at the same time the position of maximum displacement is not disturbed. Thus it is to be expected that the observations for the velocity of motion will not be as precise as the observations for the direction of motion. The two things, magnitude and azimuth of observed relative motion, are quite independent of each other.

It is desirable to have observations equally distributed over the twenty-four hours of the day; since one set requires about fifteen minutes of time, ninety-six sets, properly distributed, will suffice. The making of such a series usually occupies a period of ten days. The observations are finally reduced to one group and the mean date is considered the date of the epoch. The observations made at Mount Wilson in 1925 correspond to the three epochs, April 1, August 1 and September 15, and are more than twice as numerous as all the other ether-drift observations made since 1881. The total number of observations made at Cleveland represent about 1,000 turns of the interferometer, while all the observations made at Mount Wilson previous to 1925 correspond to 1,200 turns. The 1925 observations consist of 4,400 turns of the interferometer, in which over 100,000 readings were made. A group of eight readings gives a value for the magnitude and direction of the ether-drift function, so that 12,500 single measures of the drift were obtained. This required that the observer should walk, in the dark, in a small circle, for a total distance of 100 miles, while making the readings. Throughout these observations the conditions were exceptionally good. At times there was a fog which rendered the temperature very uniform. Four precision thermometers were hung on the outside walls of the house; often the extreme variation of temperature was not more than one tenth of a degree, and usually it was less than four tenths of a degree. Such variations did not at all affect the periodic displacement of the fringes. It may be added that while the readings are being taken, neither the observer nor the recorder can form the slightest opinion as to whether any periodicity is present, much less as to the amount or direction of any periodic effect.

The hundred thousand readings are added in groups of twenty, are averaged and then are plotted in curves. These curves are subjected to mechanical harmonic

analysis for the purpose of determining the azimuth and magnitude of the drift. In this work all the original observations have been used, without any omissions and without the assignment of weights; furthermore, there are no corrections of any kind to be applied to the observed values. The results of the analyses are finally charted in such a way as to show the variation in the azimuth of the drift throughout the day of twenty-four hours for each epoch, and the variation in magnitude is similarly charted. The observations of 1925 thus provide six curves, three showing the variation in azimuth for the different epochs and three showing the variation in magnitude. The curves are shown in Figs. 1 and 2. The dots,

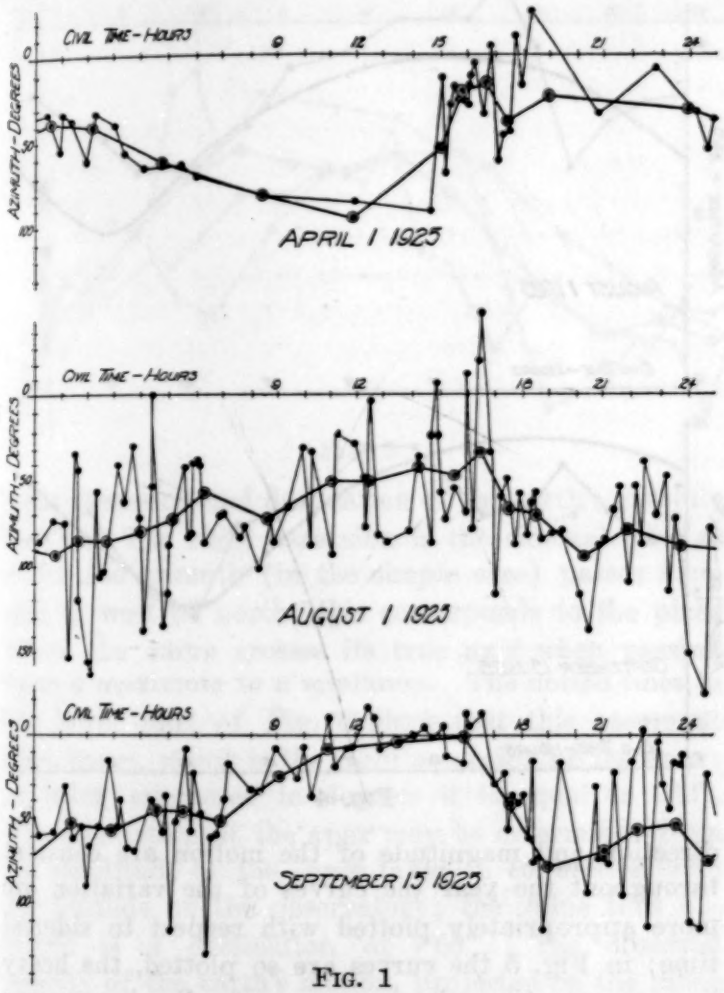

FIG. 1

connected by the light lines, represent single observations, each being the average of the readings from twenty turns of the interferometer during an interval of about fifteen minutes. The heavy line represents an arbitrary average of the single observations for the one epoch. In Fig. 1 the base line represents the twenty-four hours of the local civil day; a position on this line corresponds to a direction of motion to the north, while a point above the line indicates an easterly azimuth and one below the line, a westerly azimuth. In Fig. 2 the base again represents the hours of the civil day, while the magnitude of the ether drift, that is, the velocity of relative motion, throughout the day, is charted in kilometers per second. It is at once evident that there is something real in the observations; each curve has a definite and a characteristic form; certainly, the results are not zero, neither are they due to accidental errors of observation. The azimuth of the observed effect, Fig.

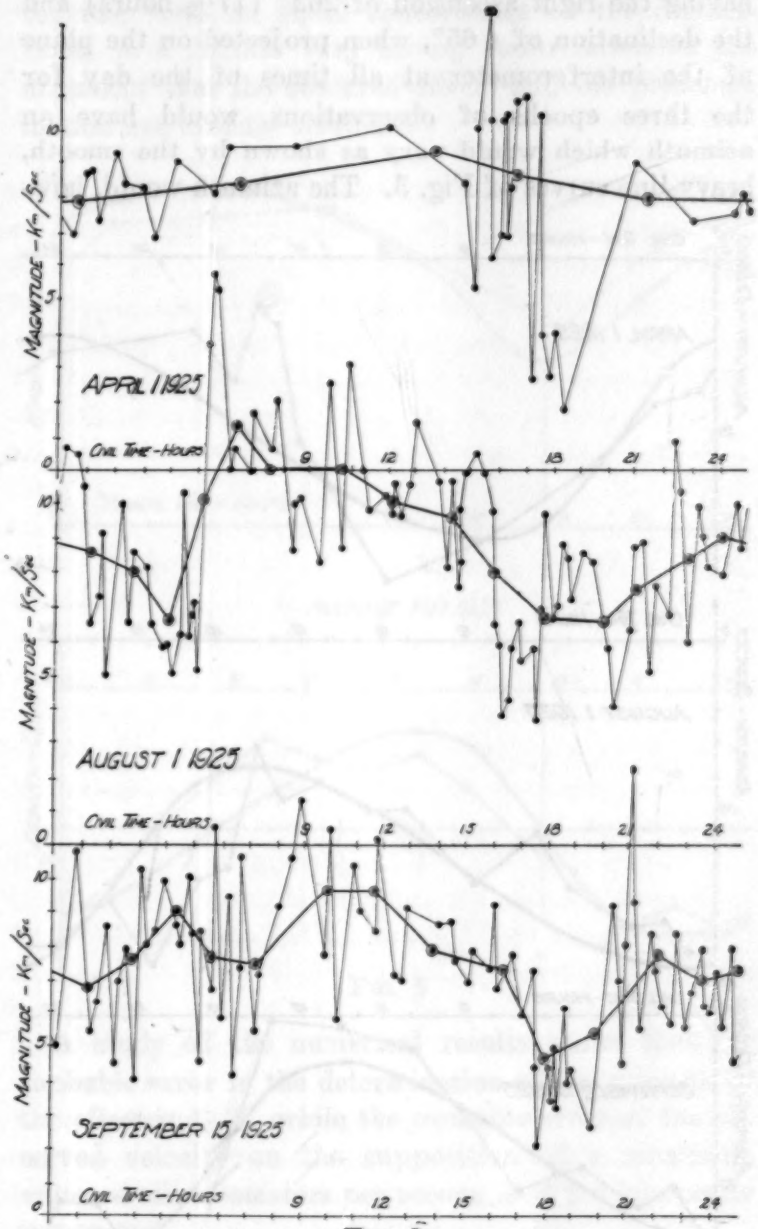

FIG. 2

1, varies in a periodic manner throughout the twenty-four hours of the day, the average being about 45° west of north, with the time of greatest westerly deviation varying with the time of year. Fig. 2 shows that the magnitude of the effect also varies periodically, with its maximum of about ten kilometers per second occurring at different times of day at different times of year.

It has been impossible to specify any effects of temperature, radiant heat, magnetism, gravitation or any other cause, which can produce the systematic variations indicated for the different epochs. The presumption was then made that the effects may be due to the motion of the earth and of the whole solar system through the ether, that is, to a real ether drift. Various graphic and numerical solutions were

made for determining the apex and velocity of such a motion. These trial solutions were checked by means of a mechanical parallelogram apparatus, and finally by a partial least-squares solution. It was found that a direction towards a point in the constellation Draco, having the right ascension of 262° (17½ hours) and the declination of +65°, when projected on the plane of the interferometer at all times of the day for the three epochs of observations, would have an azimuth which would vary as shown by the smooth, heavy-line curves of Fig. 3. The azimuth would, however, vary equally to the east and to the west of north; that is, the curve should be partly above and partly below the horizontal base line of the figure. As drawn, the curves have been arbitrarily displaced downward (westward) to match the broken line curves which show the actual results of observation, taken from Fig. 1.

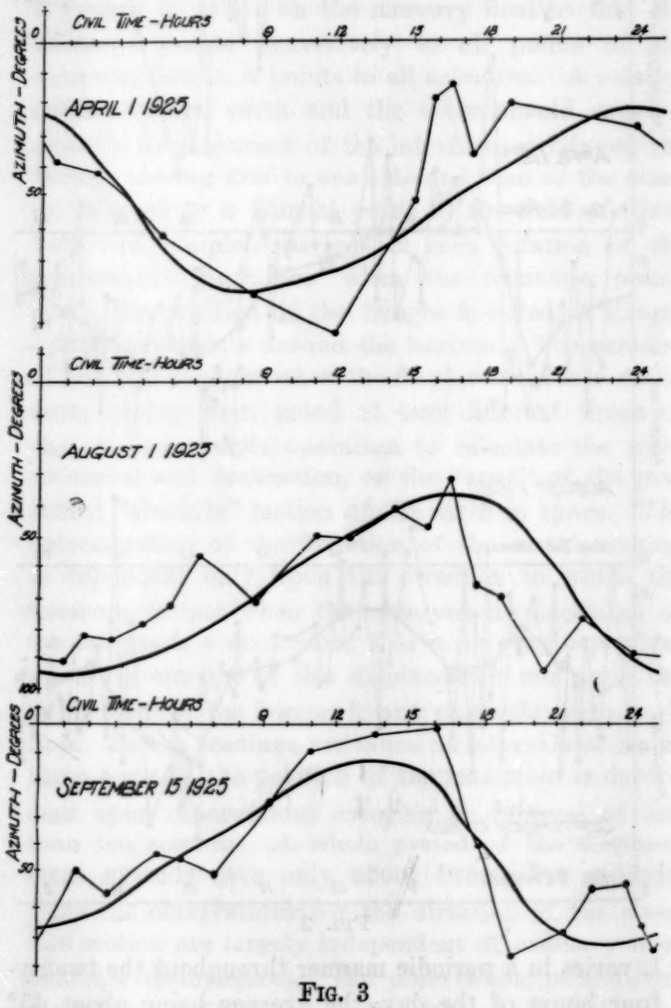

FIG. 3

If the motion has a direction towards the constellation Draco with a velocity of ten kilometers per second, which remains constant throughout the year, its projection on the plane of the interferometer would vary in magnitude throughout the day, for the three epochs of observations, as shown by the smooth curves in Fig. 4. The broken-line curves show the variation in magnitude of the observed effect, being the averages from Fig. 2.

The curves so far considered have been plotted with respect to local civil time for Mount Wilson. If the direction and magnitude of the motion are constant throughout the year the curves of the variation are more appropriately plotted with respect to sidereal time; in Fig. 5 the curves are so plotted, the heavy line representing the averages of all observations for 1925. There is a remarkable agreement of the curves for the different times of year when plotted against sidereal time; the figure shows that the concordance of the curves for the direction of motion is better than for the magnitude. In Fig. 6 the final averages of Fig. 5 are shown by the broken-line curves, while the computed effects are shown by the smooth curves. For the azimuth the curves are drawn to a scale of displacement twice that of the preceding figures, the better to bring out the remarkable agreement between the curves.

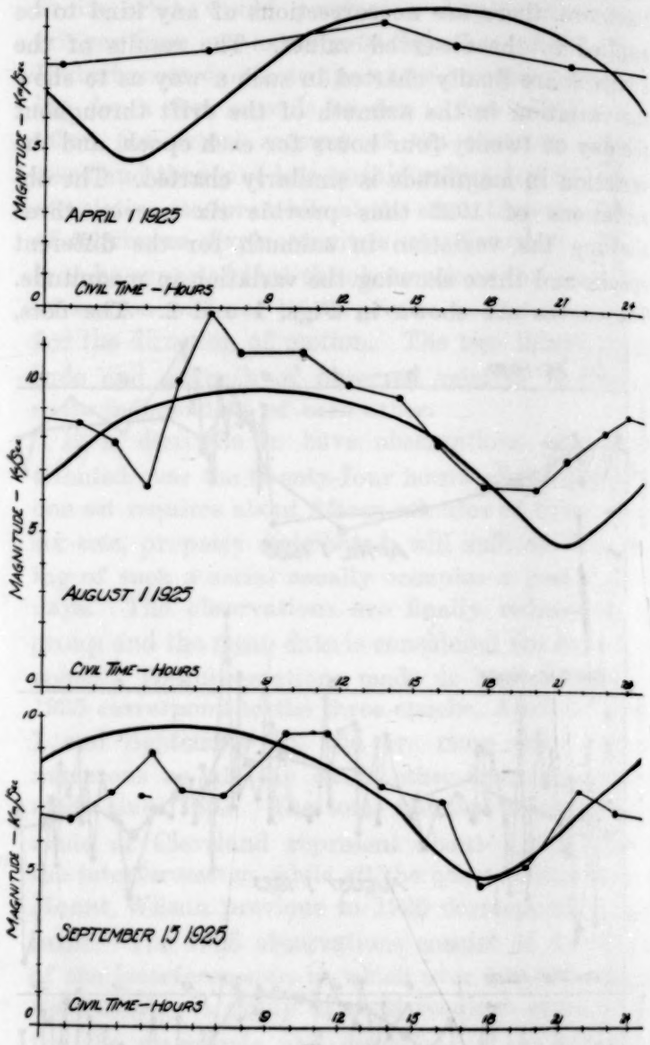

FIG. 4

As far as the observed quantities entering into these two curves are concerned, they are quite independent of each other; and each gives values of the

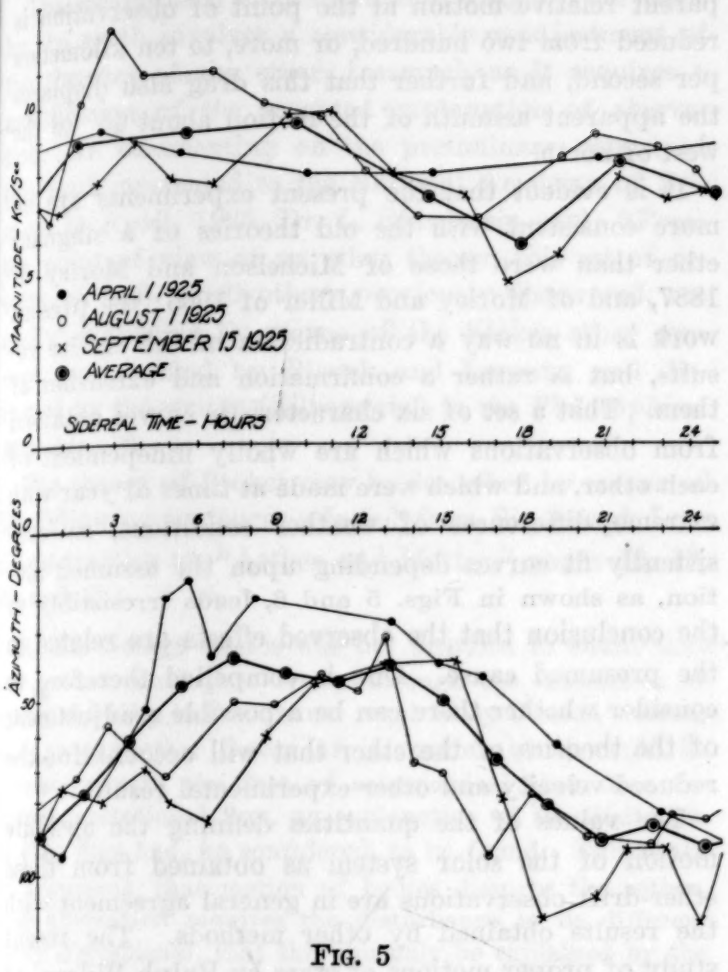

FIG. 5

right ascension and declination of the earth's absolute motion. The right ascension is the sidereal time at which the azimuth (in the simple case) passes from east to west of north; this corresponds to the place where the curve crosses its true axis when passing from a maximum to a minimum. The dotted lines in the lower part of Fig. 6 show that this occurs at 17½ hours, which is the right ascension of the apex; or being expressed in degrees it is equal to 262°. The declination of the apex may be determined from the amplitude of the curve taken in connection with the latitude of the observatory; the value thus obtained is a declination of +65°. The observed velocity of the earth's motion, projected on the plane of the interferometer, should show a daily variation in magnitude as a result of the rotation of the earth on its axis; this magnitude should drop to its minimum value at a sidereal time which is the right ascension of the apex; and should reach its maximum twelve hours from this time. Considering the latitude of Mount Wilson, 31° 14′, and the declination of the apex as just determined from the azimuth of observations, it appears that at the time of maximum the plane of the interferometer makes an angle of less than 8° with the direction of the earth's motion; thus the projection of the velocity at this time does not differ appreciably from its full value, which is then shown to be equal to ten kilometers per second. The declination of the apex may be determined from the magnitude observations, as well as from those for azimuth, since it determines the ratio of maximum and minimum values of velocity for a given latitude. The agreement of the two right ascensions derived from these independent curves, indicated by dotted lines in Fig. 6, together with an equal concordance of the declinations, is a further very strong confirmation of the argument that the observed effects and the presumed motion are directly related.

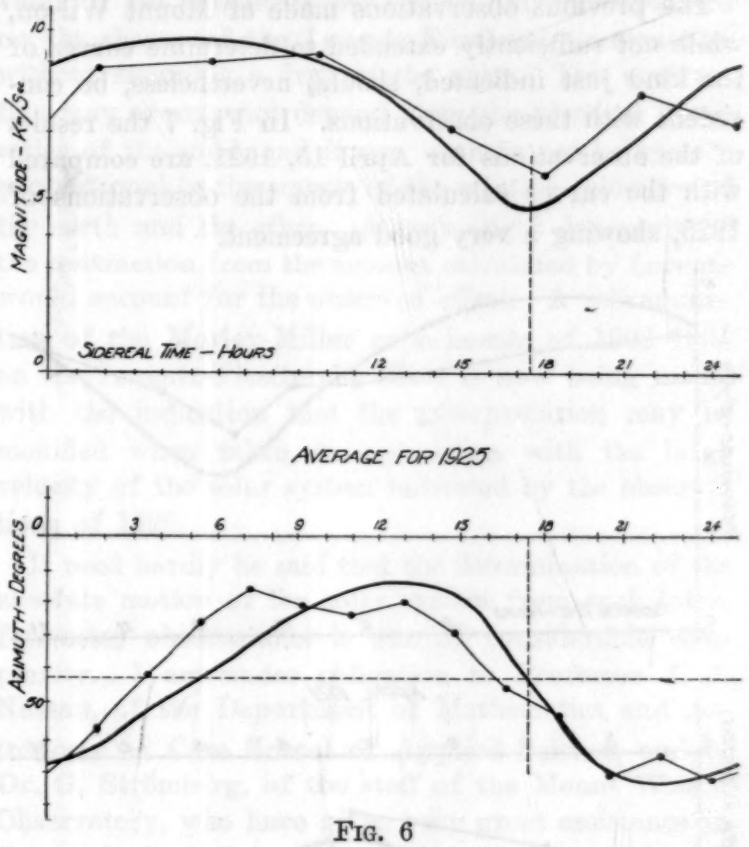

FIG. 6

A study of the numerical results shows that the probable error in the determination of the azimuth of the effect is ± 2°, while the probable error of the observed velocity on the supposition of a maximum value of ten kilometers per second is ± 0.6 kilometers per second.

The argument that the direction and magnitude of the observed ether drift is independent of local time and is constant with respect to sidereal time implies that the effect of the earth's orbital motion is imperceptible in the observations. No effect of this orbital motion has been found in these observations of 1925; this is strictly in accordance with the results obtained by Michelson and Morley in 1887 and by Morley and Miller in 1905. In order to account for this fact it is assumed that the constant motion of the earth in space is more than two hundred kilometers per second, but that for some unexplained reason the relative motion of the earth and the ether in the interferometer at Mount Wilson is reduced to ten kilometers per second; under these conditions a component motion equal to the earth's orbital motion would produce an effect on the resultant which is just below the limit of

the smallest quantity which can be measured by the present interferometer. It is for this reason that it is concluded that the velocity of the motion of the solar system is at least two hundred kilometers per second and it may be much greater. The fact that the observed effect is dependent upon sidereal time and is independent of diurnal and seasonal changes of temperature and other terrestrial causes shows that it is a cosmical phenomenon.

The previous observations made at Mount Wilson, while not sufficiently extended to determine curves of the kind just indicated, should, nevertheless, be consistent with these observations. In Fig. 7 the results of the observations for April 15, 1921, are compared with the curves calculated from the observations of 1925, showing a very good agreement.

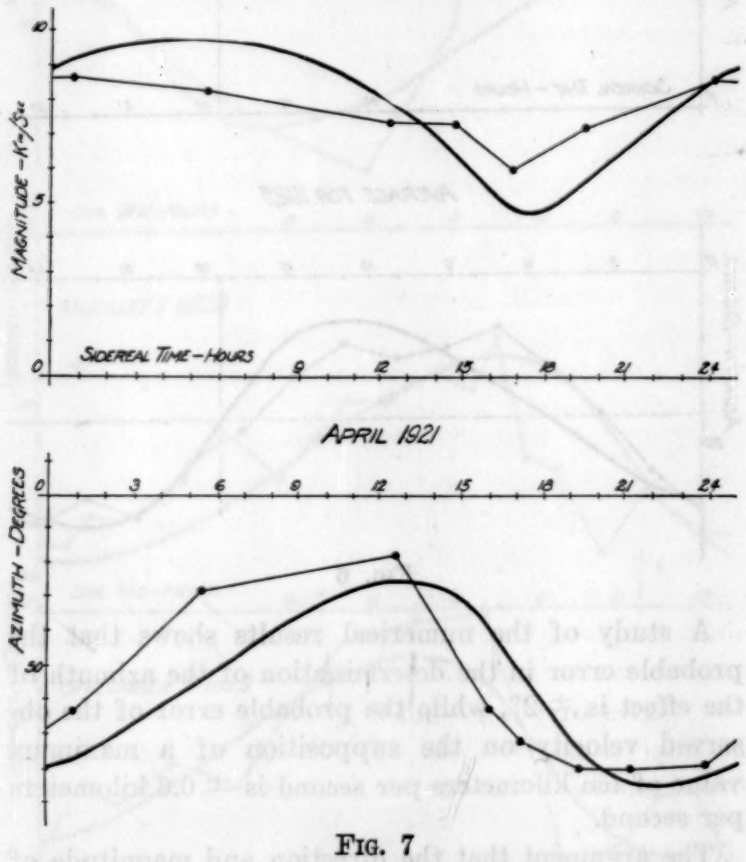

FIG. 7

The complete study of the ether-drift experiments of 1925, at Mount Wilson, leads to the conclusion that there is a systematic displacement of the interference fringes of the interferometer corresponding to a constant relative motion of the earth and the ether at this observatory of ten kilometers per second; and that the variations in the direction and magnitude of the indicated motion are exactly such as would be produced by a constant motion of the solar system in space, with a velocity of two hundred kilometers, or more, per second, towards an apex in the constellation Draco, near the pole of the elliptic, which has a right ascension of 262° and a declination of +65°. In order to account for these effects as the result of an ether drift, it seems necessary to assume that, in effect, the earth drags the ether so that the apparent relative motion at the point of observation is reduced from two hundred, or more, to ten kilometers per second, and further that this drag also displaces the apparent azimuth of the motion about 45° to the west of north.

It is evident that the present experiments are no more consistent with the old theories of a stagnant ether than were those of Michelson and Morley of 1887, and of Morley and Miller of 1905; the present work is in no way a contradiction of the earlier results, but is rather a confirmation and extension of them. That a set of six characteristic curves obtained from observations which are wholly independent of each other, and which were made at times of year with extreme differences of weather conditions, so consistently fit curves depending upon the assumed motion, as shown in Figs. 5 and 6, leads irresistibly to the conclusion that the observed effects are related to the presumed cause. One is compelled therefore to consider whether there can be a possible readjustment of the theories of the ether that will account for the reduced velocity and other experimental results.

The values of the quantities defining the absolute motion of the solar system as obtained from these ether-drift observations are in general agreement with the results obtained by other methods. The recent study of proper motions of stars by Ralph Wilson, of the Dudley Observatory, and of the radial motions of the stars by Campbell and Moore, of the Lick Observatory, give the apex of the sun's way in the constellation Hercules with a right ascension of 270° and a declination of about +30°, with a velocity of about nineteen kilometers per second. Dr. G. Strömberg, of the Mount Wilson Observatory, from a study of globular clusters and spiral nebulae, finds evidence of a motion of the solar system towards a point having a right ascension of 307° and a declination of +56°, with a velocity of three hundred kilometers per second. Lundmark, studying the spiral nebulae, finds evidence of a motion having a velocity of four hundred kilometers per second. The various determinations of the motion of the solar system are all in the same general direction and lie within a circle having a radius of 20°. Our assumed velocity of two hundred kilometers per second is simply a lower limit; it might equally well be three hundred or four hundred kilometers per second. The first assumption therefore seems to offer no difficulty. The location of the apex in the constellation Draco, at right ascension 262° and declination +65°, is within 6° of the pole of the ecliptic, that is, the indicated motion of the solar system is almost perpendicular to the plane of the ecliptic. The sun's axis of rotation points to within 12° of this apex. One can not help wondering whether there may be some dynamic significance in these facts.

The assumption that there is a drag of the ether by the earth involves a considerable readjustment of the theories of the ether, inasmuch as it requires a modification of the accepted explanation of aberration. In commenting on the preliminary report of this work presented to the National Academy of Sciences in April, 1925, Dr. L. Silberstein said: "From the point of view of an ether theory, this set of results, as well as all others previously discovered, are easily explicable by means of the Stokes ether concept, as modified by Planck and Lorentz, and discussed by the writer (Silberstein) in the *Philosophical Magazine*."[6]

The theory of Stokes may be described by means of the following sentences selected from Sir Joseph Larmor's treatise on "Aether and Matter," pages 10, 13, 35 and 36:

As Sir George Stokes was not disposed to admit that the aether could pass freely through the interstices of material bodies in the manner required by Fresnel's views, and as any other theory of its motion which could be consistent with the fact of astronomical aberration required irrotational flow, an explanation of the limitation to that flow had, he considered, to be found. This chain of argument, that motion of bodies disturbs the aether, that aberration requires the disturbance to be differentially irrotational, that this can only be explained by the dispersion of incipient rotational disturbance by transverse waves, and further that radiation itself involves transverse undulation, he regards as mutually consistent and self supporting, and therefore, as forming distinct evidence in favor of this view of the constitution of the aether. . . . The question then arises how far this explanation will extend to the case in which the aether is entrained by the matter that is moving through it. Attention has already been drawn to Sir George Stokes's considerations which would make the luminiferous property itself prevent the initiation of any rotational motion in the aether. It is in fact not difficult to prove that the energy of strain of a rigid incompressible medium of the type of ordinary matter may be expressed as a volume integral involving only the differential rotation, together with surface integrals extended over boundaries; and it follows that any local beginnings of rotational motion in an aether of elastic-solid type would be immediately carried off and distributed by transverse waves, so that if the rigidity is great enough no trace of rotational motion of the medium in bulk can ever accumulate.

There are systematic differences in the so-called constant of aberration and in standard star places as determined at different observatories, which might be explained on the hypothesis of a variation in ether drift due to differences in the local coefficient of drag. The drag at any given station may depend more or less upon altitude, local contour and the distribution of large masses of land such as mountain ranges. The ether-drift experiments have never been made at sea-level, nor, in fact, at any place except Mount Wilson, with sufficient completeness to give accurate measures of the effects. The evidence now indicates that the drift at Mount Wilson does not differ greatly in magnitude from that at Cleveland and that at sea-level it would probably have about the same value.

The reduction of the indicated velocity of two hundred or more kilometers per second to the observed value of ten kilometers per second may be explained on the theory of the Lorentz-FitzGerald contraction without assuming a drag of the ether. This contraction may or may not depend upon the physical properties of the solid, and it may or may not be exactly proportional to the square of the relative velocities of the earth and the ether. A very slight departure of the contraction from the amount calculated by Lorentz would account for the observed effect. A reëxamination of the Morley-Miller experiments of 1902–1904 on the Lorentz-FitzGerald effect is now being made, with the indication that the interpretation may be modified when taken in connection with the large velocity of the solar system indicated by the observations of 1925.

It need hardly be said that the determination of the absolute motion of the solar system from such interferometer observations is one of considerable complexity. I am under obligation to Professor J. J. Nassau, of the Department of Mathematics and Astronomy of Case School of Applied Science, and to Dr. G. Strömberg, of the staff of the Mount Wilson Observatory, who have given very great assistance in the analysis and in the mathematical solutions of various parts of the problem.

Note.—Since this paper was prepared, a very complete series of observations involving 2,000 turns of the interferometer has been made at Mount Wilson, corresponding to the epoch February 8, 1926. The general indications are that the latest observations are entirely consistent with the report here made, though it is possible that there will be slight modifications in the numerical results when all observations are combined. A definitive numerical calculation will require several months of continuous work and is now in progress.

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CASE SCHOOL OF APPLIED SCIENCE

[6] February, 1920, Vol. 39, page 161.

EXISTING PRACTICES OF POLLUTING PUBLIC WATER COURSES

Is civilization in danger of "being stewed in its own juice," or even as a preliminary smothered in a film of oil, (cold, not hot!) after an introductory sensory torture by the numerous and abundant waste products of human activity? This does not hark back

to the period of the Inquisition, or even to the days of witchcraft, but applies even to our own to-day as well as to posterity's to-morrow.

Where can you turn for an answer to any of the following questions? What agencies have been set up, what have these accomplished, what are they doing at this moment to prevent biologic wastage from bringing us, as a nation, to biologic bankruptcy?

To what extent are we piling up waste substances, ranging from denatured flivvers to denatured water and air, concentrated in quantities beyond the capacity of nature to convert such raw materials back again into her special brands of products?

How broadly, efficiently, and cooperatively are those who should be the engineers of civilization to-day working with nature to make the world safe under the rule of democracy?

What dangers are already in evidence or readily predictable?

Can these dangers be mitigated? How, when and where?

Where lies the responsibility for regulating whatever source of pollution may be amenable to regulation?

Has there been developed a general working plan, conforming to nature's laws and man's specifications? Do our minor projects, federal, state and individual, fit into this or any plan?

Reasonably complete information, general or detailed, on these points is not readily accessible. That conditions which lead to the dangerous pollution of public waters are not under adequate control is all too obvious.

Detailed discussion here is not practicable because most of the facts surrounding such pollutions are too prosaic, sufficiently obvious and yet too complicated. Some of the financial and political causes are sufficiently patent, and many of the details of destructive effects of existing practices and tendencies are known; others are reasonably predictable. But the crux of the situation which requires emphasis is that the public does not yet realize that our civilization is producing wastage and dollars faster than nature can take up the slack. Those of our methods which lead to excessive concentration of wastes actually clog and ultimately break down nature's machinery for converting wastes into renewed and useful products. The purpose here is to call attention to two facts, each of fundamental importance, but, working together as they do, are likely to become catastrophic.

Though it has now become a biological commonplace, biologists, within relatively recent years, have learned that abundant free oxygen and water are for living organisms basal factors of existence. Water and air make possible the continuously necessary cycle of matter in the world. Soluble minerals become built up into plants, plants into animals, and in due time, the bodies, both plant and animal, go back into mineral substances, to complete the cycle of "dust to dust."

Still more recently biologists have learned that to-day, as in the beginning, the condition of the waters of the earth determines not only the health and wealth of the aquatic inhabitants, but as well even the continued existence of mankind, through the primary food supply (the Plankton) and the humidity of the air.

As individuals and as a nation we have made some progress in starting the consideration of some of the questions involved in making wise use of the land, and some of the terrestrial resources. Is it not now time to consider more widely and carefully than ever before how we must treat the biologic aspects of our public waters and of our aquatic resources? Let us glance rapidly at some outstanding existing conditions. Conservatively speaking, the concentrated raw sewage and factory wastes of twenty-five million people are cast directly into the public water courses of the coastal and middle west of this continent. As a result of such wholesale concentration we choke the broad biologic process of metabolism, *i. e.*, the progressive conversion of dead organic material into its elements and the rebuilding of these elements into higher forms, including man. As a direct consequence, to-day, in many places, our rivers and shores frankly are regarded as sewers, shorn of original vegetation and devoid of useful fishes and shellfishes; moreover, with a constantly diminishing value as a source of healthful, even necessary, recreation; of peculiarly valuable types of food and of general public health.

Our best efforts at the "cheap" methods of dilution and dispersal by water result ultimately in sorrow to the eye, threats to the nostrils, a direct menace to our bodies and a ball and chain to our economic activities.

In spite of much notably successful and devotedly altruistic work by the several federal departments, by state and local health officials and civic associations, our public water courses are going from bad to worse, soon to become an economic handicap, a public menace rather than a public asset.

Scientific foresight, moreover, shows two conspicuously ominous conditions relatively near as quick results of our present practices of dumping into public waters waste materials, of which oily substances are a prominent feature.

First, the progressive curtailment of the exchange of free oxygen from the air to practically all organisms living in the water.

Second, the checking of evaporation from the surface of the waters.

It may be difficult for some of us to realize that a "free country" will be of little avail if we do not pro-

vide "free oxygen" to our public waters. This supply of oxygen comes to them in largest measure by mechanical mixture from air to water. The peasant or the wine merchant who desires to shut out the air from wine, under certain conditions, puts a thin layer of olive oil on the surface of the wine in the container. Unwittingly, on a huge scale and to a seriously large degree in the aggregate we are doing a similar thing when we permit the escape of mineral oils, anywhere, and even in small quantities. The result is twofold; we steal from the aquatic organisms the oxygen necessary for their growth, and then for good measure slowly poison them. A casual glance at many of our rivers and harbors indicates the places where ultimately the oil puts in its "dirty work." These heavy mineral tarry oils, unlike those more directly from organic sources (*i.e.*, fish and vegetable oils) are relatively resistant to change, dissolve and dissociate very slowly, and hence may persist even for years, spreading over a constantly widening area. As these oils "break up" various constituents separate out. Among these are some of the deadly chemical substances most frequently used for preventing organic growth (phenols, napthalenes, *et al.*, sold and used under various special trade and chemical names). The non-floating residue of the heavy, tarry, oily substance settles down to ultimately convert the land under the water into a sort of bitulithic pavement, obviously not conducive to the existence of many types of organisms. Here are some of the important causes of the decline of our fisheries and shellfish industries. The food supply of these is poisoned at its source, and in addition the supply of oxygen from the air is being shut off. The oxygen already dissolved in the water is diverted from its normal use, by being compelled to oxidize sewage, garbage and other waste substances, which should not be permitted to come into excessive, harmful competition with the aquatic organisms in the struggle for oxygen and for existence.

Further, the mineral oils, in addition to poisoning the organisms which compose the basal food supply for higher forms of animals, including man, equally destroy the bacteria whose function is to break up dead organic matter and thereby speed up the processes of oxidation and nitrification. But most serious of all is the fact that oils have another peculiar property, that of rapidly spreading over an ever increasing surface. Thus it is not only the quantities which may accumulate in eddies and currents, borne by wind and tide, sufficient to be a fire menace to shipping, a nuisance to bathers, but the infinitely thin layer of oil on the surface, even invisible to the unaided eye, may be sufficient to check or even to inhibit the fundamentally essential interchange of oxygen, of carbon dioxide, etc., between the air and the water. The net result is that our present practices of careless wastage of oils compels nature to carry on less efficiently her fundamentally important function of conserving energy and material, for the reason that we compel her to substitute putrefaction in place of oxidation and nitrification as major processes in nature's metabolism. In other words, our present practices of disposal of various waste substances have enormously increased in nature the amount of putrefaction, and seriously impaired the constructive processes of oxidation and nitrification. This we do by neglecting to follow nature's plan, of conducting on land some considerable proportion of the primary processes in the metabolism of waste products; but instead we cast prematurely, and therefore wastefully, into the water substances which should have primary treatment on land. So much for the ultimate effects of some pollutants on the waters. What are the predictable effects of this upon general land conditions? And the second prediction is like unto the first.

One may reasonably assume as an agreed fact that evaporation from the surface of ocean, swamp, lake and river is an important source of that air-humidity essential to terrestrial plant and animal life. The existence and constantly increasing extent of oily matter on the surface of the water will limit the quantity of water which goes into the air by evaporation from that surface. Hence it is safe inference that oil on the waters is certain to limit the water content of the air and consequently to unfavorably affect climate. The United States is notably one of the regions of the earth where aridity is at present extending or is likely to extend. Is it not a proper assumption that appreciable limitation of evaporation will appear in decreased precipitation? The facility with which we permit the escape of waste oils appears certain to become an important factor in restraining not only waste of oil but also the waste of climate and other favorable conditions of life. The sources of these oils have been studied by the U. S. Bureau of Mines. A catalogue would be long, ranging from oil well and transporting and distributing devices and practices to the careless wastage of small quantities by Mr. and Mrs. John Citizen, of Rabbit Hole, Nevada. It is the capacity of small, even minute quantities of oil to "get together" for teamwork which causes all the trouble.

What has been done and what more should be done to improve conditions which now exist or may threaten? The various federal departments have made numerous contributions on important aspects. Their wise and altruistic labors have done much to ameliorate conditions. Similarly, state legislatures, executive and judicial officers and the press have contributed in varying degrees to postpone the evil day of reckoning. At last the public is beginning to realize that human individual responsibilities competently and faithfully met are the true measures of personal and national wealth, and this *dollar economy* should

not be permitted to come into destructive competition with nature. It has become obvious that neither legislation, the courts, science, executive officials, or civilians working alone can meet the situation, and define, or allocate responsibilities and remedies remedially efficient. Cooperation, both broad and intimate, is essential if we are to overtake and conquer the economic menace arising from aquatic pollution.

Should not some of the dollars which originated in "economical methods," of waste disposal, not then even perhaps suspected of being in violation of nature's laws, be now made available for helping nature "back to normalcy," and to avoid further biologic blunders in the disposal of our waste products? In this belief, the executive committee of the National Conference on Outdoor Recreation has voted to seek the financial support necessary for initiating a non-political, authoritative, adequate disinterested survey of existing facts and factors involved in the present polluted conditions of our public water courses, assisting and cooperating to the utmost practicable degree with the existing federal and state agencies, with a view to the establishment of basic economic facts for future remedial procedure, upon which legislators, manufacturers and the public may rely, in constructive action which will at once define and defend private rights through safeguarding the public rights. This committee will aim to secure a coordination of pure science, applied science, political, economic and business science, carried on in the spirit of altruism, controlled and guided by "common sense," free from prejudice, sectional and personal interest and control: safeguarding the public, but making possible the utmost personal latitude of action within the limits of biological safety.

GEORGE WILTON FIELD

WASHINGTON, D. C.

AWARDS OF THE JOHN SIMON GUGGENHEIM MEMORIAL FELLOWSHIPS

THE appropriation of $100,000 for the assistance of young American scholars and artists during the year 1926–27 has been announced by Henry Allen Moe, secretary of the John Simon Guggenheim Memorial Foundation. This foundation was established a year ago with a fund of $3,000,000 by former United States Senator and Mrs. Simon Guggenheim, as a memorial to a son who died on April 26, 1922.

Thirty-seven new Fellows have been appointed from 18 states, ranging from Georgia to Washington. The list includes five women. Three artists are appointed for creative work in painting, three musicians for creative work in musical composition, and the research appointments are for work in a wide range of subjects. Among the fellows for 1926–27 are members of the faculties of 22 colleges and universities. Harvard University leads with four fellows; the University of Chicago has three; the University of Cincinnati, three; the University of Wisconsin, two; and Yale University, two. Seven of the fellows for 1926–27 are not at present affiliated with any educational institution.

The Guggenheim Foundation offers to the young productive scholars and artists of the country opportunities to carry on research and creative work, chiefly abroad. Applicants are required to present definite projects for research in a given field of knowledge, or projects for creative work in some one of the fine arts.

The fellowships are tenable anywhere in the world, for any period, long or short. The stipend is usually $2,500 for a period of twelve months, but in every case is adjusted to the needs of the individual appointed. The fellowships are open on equal terms to men and women, being citizens of, or permanent residents in, the United States, of every race and creed. The normal age limits of fellows are twenty-five and thirty-five years.

The appointments to fellowships just announced were made on the recommendation of the committee of selection of the foundation, consisting of: President Frank Aydelotte, Swarthmore College, *chairman*; President Frederick C. Ferry, Hamilton College; Dean Virginia C. Gildersleeve, Barnard College; Professor Charles Homer Haskins, Harvard University; and Dean Carl E. Seashore, The State University of Iowa.

Among the thirty-seven fellowships awarded are the following in the natural and exact sciences:

Dr. Wallace Reed Brode, research chemist, Bureau of Standards, Washington, D. C.—appointed for research on the absorption spectra of simple azo dyes, principally with Professor Arthur Hantzsch at the University of Leipzig, Germany. This involves a continuance of research carried on by Dr. Brode for his doctor's degree at the University of Illinois, and other researches, in the field in which he has published a number of papers in the past five years.

Dr. Royal Norton Chapman, professor of entomology, University of Minnesota—appointed to make an investigation of the problem of the relation of the abundance of insects, particularly destructive insects, to changing environmental conditions, principally at the European Parasite Laboratory, Le Mont Fenouillet, Hyeres, France, and the Rothamsted Experiment Station, England. Dr. Chapman has made and published studies of importance to the milling and cold storage industries, notably his "Insects in Relation to Wheat Flour and Wheat Flour Substitutes," "Observations on Mites infesting Flour

and Mill Feed,'' and ''Insects infesting Stored Food Products.''

Dr. Arthur H. Compton, professor of physics, University of Chicago, will continue his study of the problem of the nature of radiation, in consultation with European authorities. Dr. Compton's work during the last few years has placed him in a unique position regarding this problem, the solution of which is of the greatest importance in the advancement of physical science.

Dr. Alfred Edwards Emerson, associate professor of zoology, University of Pittsburgh—appointed for certain investigations concerned with the problem of the ontogenetic and phylogenetic origin of the castes of termites, at certain laboratories in Sweden and Italy. Dr. Emerson has carried on fundamental research in this field since 1919. He has made two journeys to British Guiana for the purpose of this research, and he now intends to examine the known species of termites in European collections.

Dr. Edwin Crawford Kemble, assistant professor of physics, Harvard University—appointed to make certain studies in the field of the new quantum theory, principally with Professors Born and Heisenberg at the University of Göttingen, Germany. Dr. Kemble's research work has been concerned principally with the application of the quantum theory to the interpretation of band spectra and to the related problem of the temperature variation of the specific heats of gases. He has published numerous articles on the subject of these researches.

Dr. Ernest Preston Lane, assistant professor of mathematics, University of Chicago—appointed to make a comparative study of the methods of investigation in the field of projective differential geometry used by American and Italian geometers. Dr. Lane was a pupil of Professor Wilczynski, of the University of Chicago, who developed methods of exceptional generality and power in the domain of analytical projective geometry. He will go abroad to become familiar with the methods of investigation developed by the Italian school of geometers and at the same time will bring complete understanding of Wilczynski's methods to the Italian school.

Dr. Julian Herman Lewis, associate member, Otho S. A. Sprague Memorial Institute; assistant professor of pathology, University of Chicago; pathologist, Provident Hospital, Chicago—appointed for a study of the fundamental nature of immunity phenomena, with particular reference to the relation of chemical constitution to biological specificity; and to study the chemical and immunological specificity of proteins isolated from organs. Dr. Lewis is a negro. He holds the degrees of A.B. and M.A. from the University of Illinois; Ph.D., Magna Cum Laude, from the University of Chicago; and M.D. from the Rush Medical College. He was elected to Sigma Xi, Honorary Scientific Fraternity, and Alpha Omega Alpha, Honorary Medical Fraternity, and while at Rush Medical College was awarded the Benjamin Rush Medal as the highest standing student of his class. He has carried on fundamental research for several years and has published numerous papers.

Dr. Harold Myers Marvin, assistant professor of medicine, Yale University School of Medicine—appointed for research in the field of cardiovascular physiology in Sir Thomas Lewis' Laboratory at the University College Hospital, London, England. During the past five years Dr. Marvin has been in charge of the work in heart disease at the New Haven Hospital. His work with Sir Thomas Lewis will be a continuation of work in the same field, the normal and abnormal physiology of the heart and circulation, in which he has published several papers.

Dr. Linus Carl Pauling, department of chemistry, California Institute of Technology, Pasadena, California—appointed for certain theoretical and experimental researches concerning the interior of the atom, principally with Professors A. Sommerfeld, at the University of Munich, Germany, and Niels Bohr, at Copenhagen, Denmark. Dr. Pauling has for the past four years prosecuted researches important in this general field and has published numerous articles.

Dr. Franklin Pearce Reagan, assistant professor of comparative anatomy, on leave from the University of California, under appointment to Indiana University—appointed for the continuation of studies of the structure and development of the earliest blood vessels of Mammalian Embryos, in certain laboratories of England and Scotland. Dr. Reagan has been working in this field for the past six years. Under the auspices of the foundation he will carry on a new comparative study of embryos of certain rare and almost extinct Australian a-placental mammals which represented, so far as they are now represented, the ancestors of the present-day mammals.

Dr. Gladys A. Reichard, instructor in anthropology, Barnard College, Columbia University—appointed to make a study concerning itself principally with defining the art style of Melanesia, with Professor Thilenius, director of the museum at Hamburg, Germany. Miss Reichard is the author of a grammar of the language of the Wiyot Indians. In the field in which she proposes to work under the auspices of the foundation, she has written ''Literary Forms and the Dissemination of Myths,'' and ''The Complexity of Rhythm in Decorative Art.''

Dr. Ralph A. Sawyer, assistant professor of physics, University of Michigan—appointed to make a study of spectral series relations in extreme ultra-violet metallic spectra and the correlation of the results with modern theories of atomic structure, principally in the laboratory of Professor F. Paschen, president of the Imperial Physico-Technical Institute, Charlottenberg, Germany. Dr. Sawyer worked with Professor R. A. Millikan on the opening up of the investigation of the whole extreme ultra-violet field. His earlier work was experimental in nature, but lately has dealt with the analysis of the results of experimental spectroscopy.

Dr. Ellis Bagley Stouffer, professor of mathematics, University of Kansas—appointed for a comparative study of three general methods of investigation in the field of projective differential geometry, and also research

into certain problems in the same field. Dr. Stouffer's proposed studies are in the same field as Dr. Lane's, also a fellow of the Guggenheim Foundation for 1926–27. He has published numerous papers in his proposed field of investigation.

Dr. Glenn Thomas Trewartha, instructor in geography and climatology, University of Wisconsin—appointed for geographic investigations of certain selected type areas in Japan and China. Dr. Trewartha's principal researches for the past two years have been on the subject of the relationship of Wisconsin's physical environment to its pre-eminence as a dairy state. In preparation for his research in Japan and China he has had a thorough academic training in the geography, climatology and the diplomatic history of the Far East. His researches under the auspices of the foundation will be entirely in the field.

Dr. Norbert Wiener, assistant professor of mathematics, Massachusetts Institute of Technology, Cambridge—appointed for researches on Bohr's almost periodic functions, on haphazard motion, on periodogram analysis, and other topics, connected with one another by forming extensions of the ordinary Fourier series and Fourier integral theory. Dr. Wiener has been invited by the Mathematical Institute of the University of Göttingen to deliver a course of lectures on the subject of his researches, and the book which will result from those researches has already been tentatively accepted as a volume of a series of important mathematical works.

The Fellowship awarded to Dr. Coleman R. Griffith, assistant professor of psychology, University of Illinois, for research in problems of child psychology, principally at the University of Giessen, Hesse, Germany, for 1925–26, has been transferred to the 1926–27 group.

SCIENTIFIC EVENTS

THE OCEANOGRAPHIC STATION AT SALAMMBO, NORTH AFRICA

ON February 14 the oceanographic station at Salammbo, near Tunis, was formally opened to the public, and the station is now engaged in carrying on the studies indicated by its title. It is under the control of the direction generale des Travaux Publics of the Regenal de Tunis Protectorate de France and the funds have been largely supplied by the profits accruing from the sale of fish, caught in the Lake of Tunis—a monopoly enjoyed by the station. This monopoly was granted mainly for the control of the fishing, for the lake is a fruitful breeding ground for many marine fishes and secondly, for the control of prices in the market and for the profits accruing therefrom. The profits surpassed expectation and late in 1922 the foundations of the station were laid. The building is 33.4 m long by 33.3 m wide, two stories high, built of masonry, covered by stucco in the fashion of the country.

The building is supplied with sweet water from the Tunis water supply and with salt water from an underground reservoir, pumped from the sea and filtered as at Naples and New York. Lighting and pumping are done by electricity.

On the ground floor are laboratories for research, a well-equipped chemical laboratory, a laboratory for photography well supplied with apparatus; a large room for the reception of material with large tanks for handling and sorting; a studio for artistic work, adequate rooms for supplies and collections and a large hall for lectures.

In the upper floor are the aquaria, now fourteen in number, a museum displaying fishing apparatus and models, together with prepared specimens of sea animals; a tank room exhibiting in small tanks the invertebrates and small fishes; the office of the director, the library, and other research rooms. The whole is well lighted and admirably arranged.

The floating equipment consists of a steamer—the *Raymond Lane* of 700 tons—which also serves to care for the lighthouses of the Gulf of Tunis: a motor boat 17 m long—the *Andre Choleski* and an auxiliary sail boat 14 m long. Connected with the work of the station at six other points along the coast are boats used in the inspection of fisheries and in the researches of the station. At the present time the principal efforts of the station are: (1) the hydrology and biology of the Lake of Tunis; (2) the study of migratory fishes; (3) the biology of sponges, and (4) investigations upon fishing appliances best adapted to increase the values of the fisheries.

The publications comprise bulletins and notes. Three bulletins have already been issued and one of the notes. Exchange of publications with similar institutions is cordially invited. Qualified students of marine biology are welcome from any country.

The location of the laboratory is charming. It lies between the two ponds, commonly called the ports of ancient Carthage. The byrsa, or citadel, is a few hundred yards away, and along the shore are the remains of a vast fortifying wall. It is easily reached from Tunis by an electric railway in about 30 minutes. The station is under the direction of Monsieur H. Heldt, who is undertaking researches along several important lines.

C. L. BRISTOL
PROFESSOR EMERITUS OF BIOLOGY,
NEW YORK UNIVERSITY,
TUNIS

THE RAWSON-MACMILLAN SUB-ARCTIC EXPEDITION OF THE FIELD MUSEUM

COMMANDER DONALD B. MACMILLAN, the arctic explorer, has been commissioned by the Field Museum of Natural History to lead an expedition into the sub-arctic to collect zoological, geological, anthropological and botanical specimens for the institution.

Frederick H. Rawson, chairman of the board of the Union Trust Company, is financing the expedition. The venture will be known as the Rawson-MacMillan Sub-Arctic Expedition of the Field Museum for 1926.

Present plans call for the expedition to leave Wiscasset, Me., around June 19, for a several months tour of Labrador, Baffin Island, South Greenland and Ellesmere Land. The *Bowdoin,* an auxiliary type of Gloucester fishing schooner equipped with sails and a power plant, will be used by Commander MacMillan to take his party into the arctic. The ship is owned by Commander MacMillan, and was used by him in three previous arctic expeditions.

On his last arctic dash, the vessel carried a total of eleven men. On this trip the *Bowdoin* will carry ten men, according to present plans. The vessel, only 89 feet long, can not accommodate more than ten men and the supplies and equipment needed for the journey without uncomfortable crowding. No professional sailors will be taken on the *Bowdoin.* Commander MacMillan and several of the scientists to go on the vessel are expert wheelsmen and will take turns at the wheel.

Two staff men of the museum have been assigned to the expedition, and it is probable that outside scientists, including a competent geologist, mineralogist and botanist, will be invited to assist the museum men. The museum staff men to accompany Commander MacMillan are Alfred C. Weed, assistant curator of fishes, and Ashley Hine, bird taxidermist and collector. Mr. Weed, a specialist on fishes, is also an all-around collector, who has been on several museum expeditions. Mr. Hine is an expert taxidermist and is well known for his skill in mounting birds. Dr. Walter Koelz, of the United States Bureau of Fisheries, may be a member of the party, the entire personnel of which will be announced by the director later.

Rowe B. Metcalf, of Providence, R. I., has outfitted a second vessel to trail the *Bowdoin.* Mr. Metcalf may carry some of the scientists and equipment.

The first stop after the vessels leave Wiscasset will be Sydney, N. S., where the last of the supplies will be taken on board. Battle Harbor, Labrador, will be the first stop in the area to be explored. The expedition will maintain its base on shipboard, and make stops at various points while the scientists go ashore for their specimens. Complete radio equipment will be taken along to keep the party in touch with civilization.

This is the first Field Museum expedition to penetrate the sub-arctic. It is the intention and wish of President Stanley Field and the board of trustees of the museum to make as complete a scientific survey as possible of the sub-arctic by securing general collections of the natural history and ethnology of that area. Attainment of this objective would give the museum an adequate representation of the life of the Eskimo, along with mammal, bird, fish and geological specimens of the sub-arctic, in which the institution is deficient.

THE FIRST MEETING OF THE EASTERN SECTION OF THE SEISMOLOGICAL SOCIETY OF AMERICA

THE first meeting of the recently organized Eastern Section of the Seismological Society of America will be held at the Carnegie Institution, Washington, D. C., on May 1. The national officers of the society are Bailey Willis, *president;* Harry O. Wood, *first vice-president;* N. H. Heck, *second vice-president;* M. Hall McAllister, *third vice-president,* and S. D. Townley, *secretary-treasurer.* The temporary section officers are James B. Macelwane, *chairman;* Ernest A. Hodgson, *vice-chairman,* and Nicholas H. Heck, *secretary-treasurer.*

The business meeting will be held at 9:00 a. m. for the reading of the reports of the temporary officers, discussion of permanent organization, election of officers, vote of place of next meeting and amount of section dues. This will be followed by a general scientific session at 9:30, which will be continued in the afternoon at 2:30. The program consists of a symposium on the present status of seismology in the United States and is made up of the following papers:

The Work of the Seismological Society of America (20 minutes): BAILEY WILLIS.

Seismology in Canada (20 minutes): ERNEST A. HODGSON.

The Seismological Work of the U. S. Coast and Geodetic Survey (20 minutes): E. LESTER JONES.

(Subject to be announced): JOHN R. FREEMAN.

The Jesuit Stations in the United States—A Retrospect (15 minutes): JAMES B. MACELWANE, S.J.

Seismology, the Public and Science Service (20 minutes): WATSON DAVIS and JAMES STOKLEY.

The Montana Earthquake in Relation to the Geology of the Region (20 minutes): J. T. PARDEE.

The Relation of Isostasy to Seismology (10 minutes): W. BOWIE.

The Texas Earthquake of July 30, 1925 (10 minutes): FRANK NEUMANN.

The Geology of the St. Lawrence Earthquake (20 minutes): ARTHUR KEITH.

The Engineering-Economic Foundation and Earthquake Hazard (20 minutes): HOLLIS GODFREY.

The Geological Society of Washington is joining with the Eastern Section in this meeting. It is represented in the above program by J. T. Pardee and Arthur Keith.

TRIBUTE TO PROFESSOR CHARLES SCHUCHERT

UPON Professor Charles Schuchert's recent return from a sojourn in Texas, he was presented with an engrossed copy of the following tribute from his colleagues:

The curators of the Peabody Museum gladly avail themselves of the opportunity afforded them by Professor Schuchert's retirement to place on record their appreciation of his long and devoted service to the Museum and to Yale.

Coming to Yale from the United States National Museum in 1904 to succeed Professor Beecher as professor of paleontology and curator of the geological collections, Professor Schuchert's museum duties at once became threefold, for this curatorship carried with it the administrative direction of the museum and in addition he was elected secretary of the board of trustees.

As curator, Professor Schuchert's interests lay chiefly in the field of invertebrate paleontology, and through his efforts the collections along these lines have been more than doubled. Many of these were secured in connection with his own studies, notably those from the early Devonian of Europe, the early Silurian of Ontario, the Devonian of Gaspé Peninsula, the Silurian of New Brunswick, the vast collections from the Ordovician of western Newfoundland, and those from the Pennsylvanian of the oil fields of Oklahoma and Texas. Other collections made under his direction by graduate students have formed the basis of monographic studies pursued under his guidance, such, for example, as the great collections from Anticosti Island, from the Silurian strata of Arisaig, and from the Devonian of Oklahoma and of Tennessee. Still other collections have been secured for projected studies. In many instances these were obtained at slight or no cost to the museum, and frequently at Professor Schuchert's own personal expense, for when funds were lacking to make desirable purchases or to send good students into the field, his generosity met the need. In addition to this material increase in the way of collections, his researches have brought honor and distinction to the institution he has so faithfully served.

As an administrator, Professor Schuchert has been an equally devoted and able leader, always interested in the several departments of the museum and sympathetic toward their needs. His never-failing enthusiasm and his singular devotion to the pursuits of science have always been an inspiration to students and to colleagues alike. During his administration, he never ceased to keep before the university authorities the need for a new museum, and when this building became a probability, he devoted much time to consideration of plans for it. It was one of the many unforeseen results of the great war that it did not fall to his lot to carry those plans into execution, for the two years that were expected to elapse between the demolition of the old museum and the construction of the new lengthened into seven. He therefore relinquished his administrative duties in 1922, but at the urgent request of his colleagues retained his curatorship and his trusteeship until the new museum was completed.

In his retirement from the service of the museum, Professor Schuchert carries with him the affectionate esteem of his fellow-workers and their wish that he may have many more years of joyful labor upon the researches to which he is now devoted.

WESLEY R. COE — GEORGE G. MACCURDY
CARL O. DUNBAR — MALCOLM R. THORPE
WILLIAM E. FORD — ELEANORE W. PARMELEE
RICHARD S. LULL

SCIENTIFIC NOTES AND NEWS

DR. FREDERICK P. GAY, professor of bacteriology in Columbia University, College of Physicians and Surgeons, has accepted appointment as American visiting professor to Belgium for 1926–1927. The appointment was made by the C. R. B. Educational Foundation, Inc., established by the commission for relief in Belgium. Professor Harlow Shapley, director of the Harvard College Observatory, is the visiting professor for the present year and is now in Belgium.

DR. JABEZ NORTH JACKSON, of Kansas City, president of the Southwest Medical Association, has been elected president of the American Medical Association, succeeding Dr. Wendell Phillips, of New York. The next annual meeting is to be held in Washington, D. C.

THE honorary degree of doctor of laws will be conferred upon Professor Niels Bohr, of Copenhagen, by the University of Edinburgh in June.

SIR JAMES FRAZER, professor of social anthropology at the University of Liverpool, has been made a commander of the Legion of Honor by the French government.

THE Bessemer Gold Medal for 1926 of the British Iron and Steel Institute has been awarded to Sir Hugh Bell. We learn from *Nature* that the medal, the award of which is made in recognition of outstanding services in the advancement of the art of the manufacture of iron and steel, will be presented to Sir Hugh Bell at the annual meeting of the institute on May 6, by the incoming president, Sir W. Peter Rylands.

THE proceeds of the Daniel-Pidgeon Fund of the Geological Society of London for 1926 have been awarded to Dr. David Williams, who proposes to investigate the geology of the country between Snowdon and the Carnedds.

DR. L. FREDERICQ, Liège, has been elected to fill the vacancy from the death of Bergonié in the list of corresponding members of the French Academy of Sciences.

AT the concluding meeting of the International Electro-Technical Commission in New York on April 22, Guido Semenza, of Milan, Italy, was reelected president; Col. R. E. Crompton, of London, was elected honorary president, and Sir Richard Glazebrook, of Cambridge, England, honorary secretary. It was decided to hold the next meeting in Italy in 1927.

A TRIBUTE to John Hays Hammond, whose seventy-first birthday was on March 31, will be paid on May 3, the observance centering in a dinner to be given at the Waldorf Hotel, in New York, by a "company of friends." Dinners, timed to coincide with the New York dinner, will be held in the Rand in South Africa and in Paris, London, Berlin, Manila, Tokio, Lisbon, Salt Lake City, Denver and San Francisco.

FRIENDS of Dr. Charles Davison, emeritus professor of surgery, University of Illinois College of Medicine, gave a dinner in his honor at the Congress Hotel, on April 16, at which a bust of the guest of honor made by Lorado Taft was presented to the University of Illinois.

DR. ROY W. MINER, of the American Museum of Natural History, has been elected by the council of the New York Academy of Science to the offices of recording secretary and librarian of the academy.

DR. N. H. STEWART, of Bucknell University, was elected president of the Philadelphia Academy of Science at the recent Harrisburg meeting.

DR. JULES DRACH, professor of mathematics at the University of Paris, has been appointed visiting exchange professor for 1926–27.

DR. GEORGE H. PARKER, professor of zoology and director of the Zoological Laboratory at Harvard University, will attend the third Pan-Pacific Science Congress, at Tokyo, from October 27 to November 9, 1926.

DR. B. W. KUNKEL, professor of biology at Lafayette College, has returned to Easton, Pa., from London, where he spent the first half year in Professor Julian Huxley's laboratory at King's College. At the meeting of the British Society for Experimental Biology on January 8 he presented a paper entitled "A Growth Nomograph for Gammarus Chevreuxi."

DR. O. T. NICHOLAS, fellow of Trinity College, Cambridge, and tutor in geology, and Dr. A. H. Westergaard, of the geological survey of Sweden, will be guests of the Princeton University summer school of geology, which will undertake a geological survey trip this summer.

DR. YANDELL HENDERSON, professor of applied physiology at Yale University, lectured on February 1, before the faculty and students of the Medical School of Cairo, Egypt, on "Some Adventures in Respiration." He will spend the spring term working in the physiological laboratory at the University of Cambridge.

DR. OSKAR KLOTZ, professor of pathology and bacteriology in the University of Toronto, delivered the Gordon Bell Memorial Lecture, Winnipeg, on April 9. Dr. Klotz sails on May 1, for Lagos, West Africa, where, at the request of the Rockefeller Foundation, he will investigate yellow fever for six months.

DR. GEORGE P. MERRILL, of the United States National Museum, lectured in April on the "Origin, Constitution and Textures of Meteorites," before the department of geology of Bryn Mawr College.

DR. S. C. LIND, of the Fixed Nitrogen Research Laboratory, lectured on March 10 in the school of chemistry at the University of Minnesota. His subject was "Chemical Action of Gaseous Ions produced by Alpha Particles."

PROFESSOR W. LASH MILLER, of the University of Toronto, lectured on April 13 in the school of chemistry at the University of Minnesota. His subject was "The 'Outsider' in Scientific Research."

PROFESSOR E. F. BURTON, of the department of physics of the University of Toronto, is delivering a series of five lectures on "Physics of the Ultramicroscope and the Optical Properties of Suspended Particles and Colloidal Cells," which the Mayo Foundation of the University of Minnesota has asked him to give in certain centers, namely, the Mayo Foundation, April 5; Washington University (St. Louis) Medical School, April 12; the University of Iowa Graduate School, April 13; the Des Moines Academy of Medicine, April 14; the Graduate School of the University of Minnesota, April 16. Other lecturers at these centers have been Professor Millikan, California Institute of Technology; Professor Gortner, University of Minnesota; Professor Osterhout, Rockefeller Institute; Professor Chambers, Cornell University, and Professor Fischer, University of Cincinnati.

PROFESSOR DOUGLAS JOHNSON, of Columbia University, gave the invitation address before the Ohio Academy of Science at the annual meeting in Columbus on April 9. On April 14 he was the Phi Beta Kappa orator at Denison University. In both instances he spoke on the "Evolution of the Grand Canyon District."

DR. GUSTAVUS J. ESSELEN, JR., of Skinner, Sherman and Esselen, Inc., industrial chemists, Boston, recently delivered the last of the series of three John Howard Appleton lectures for this year at Brown University on the subject of "Cellulose Chemistry as applied to Rayon."

DR. KATHERINE COWARD, of London, spoke on the "Chemistry of Vitamins" at the open meeting of the Kappa Mu Sigma in Kent Chemical Laboratory, University of Chicago, on April 9.

DR. ARTHUR SCHUELLER, of Vienna, addressed the New York Neurological Society on April 6 at the New York Academy of Medicine.

PROFESSOR CHARLES FABRY, professor of physics at the Sorbonne, Paris, delivered the eleventh Guthrie Lecture of the Physical Society of London on April 23. The title of the lecture was "The Absorption of Radiation by the Upper Atmosphere."

PREPARATIONS are being made in Italy to commemorate next year in suitable form the centenary of the death of the great Italian scientist, Alessandro Volta. The leading scientific and technical associations are joining together in organizing a comprehensive program which will comprise, among other items, international congresses on physics, telegraphy and radio communication, while an International Exhibition of Electrical Communications is to be held in Como.

DR. DOUGLAS STEWART, director of Carnegie Museum of Pittsburgh, died on April 21, aged fifty-three years.

DR. LOUIS A. HERDT, professor of electrical engineering at McGill University, died on April 11.

VICE-ADMIRAL SIR JOHN FRANKLIN PARRY, known for his work in hydrography and navigation, died at his home in England, on April 23, aged sixty-three years.

SIR HARRY BROOKS ALLEN, professor of pathology and dean of the faculty of medicine in Melbourne University, Australia, has died, aged seventy-one years.

SIR JOHN BURCHMORE HARRISON, director of the Department of Science and Agriculture, in British Guiana, the author of numerous papers on the chemistry of tropical products, died on February 8, aged sixty-nine years.

DR. A. WITZ, formerly professor of physics in the Catholic University of Lille, who was known for his work on thermodynamics and on internal combustion engines, died on January 25, aged seventy-seven years.

PROFESSOR THOMAS JONESCU, a well-known Rumanian surgeon and director of the Institute of Experimental Surgery at the University of Bucharest, died on March 28, at the age of sixty-six years.

THE United States Civil Service Commission has announced an open competitive examination for the positions of associate physicist at a salary of $3,000 and assistant physicist at a salary of $2,400, receipt of application for which will close on May 25. The examinations are to fill vacancies in the Bureau of Standards and the Bureau of Mines, Department of Commerce, and in positions requiring similar qualifications.

THE American Geophysical Union is holding its seventh annual meeting in Washington, D. C., on April 29 and 30. The general meeting of the union will be held on the second day in the building of the National Academy of Sciences and there will be separate meetings of the several sections of the organization on both days. After a business session to receive reports of officers and section chairmen and elect officers, the general meeting will conduct a symposium on the "Constitution of the Earth," with general discussion following brief summaries of various aspects of the subject by designated speakers. Dr. C. G. Abbot, of the Smithsonian Institution, who is chairman of the section of meteorology, is expected to return to Washington from his trip to Southern Asia and Africa in time to preside at the meeting of that section.

THE American Society of Zoologists will hold its twenty-fourth annual meeting at Philadelphia, December 27, 28 and 29, in connection with the meeting of the American Association for the Advancement of Science.

THE American Society of Mammalogists is holding its eighth annual meeting from April 27 to 30 at the American Museum of Natural History, New York.

THE first meeting of the recently organized Massachusetts branch of the Society for Experimental Biology and Medicine was held on April 13 at the Harvard Medical School. The following program was presented: "The Action of Certain Compounds on the Autonomic Nervous System," Reid Hunt. "The Effect of Loss of Skin and of Muscle on the Development of Spinal Ganglia," Samuel R. Detwiler. "The Velocity of Venous Blood to the Right Heart in Human Beings," Herman Blumgart and Soma Weiss. "Changes in the Blood during Exercise," Lawrence J. Henderson, Arlie V. Bock, David B. Dill, Louis M. Hurxthal and John S. Lawrence. The following committee has been appointed to consider policy: Walter B. Cannon, James L. Gamble, George H. Parker, Frederick H. Pratt, Hans Zinsser. Dr. Edwin J. Cohn is chairman of the society and Dr. Percy G. Stiles, secretary.

THE Tennessee Academy of Science and the Tennessee Archeological Society held a joint meeting at Nashville on March 24. Dr. Warren K. Moorehead, director of the department of archeology, Phillips Academy, Andover, Massachusetts, delivered an address on "Important Archeological Discoveries in the South." Dr. Louis J. Bircher, associate professor of physical chemistry in Vanderbilt University, gave an illustrated lecture in the evening on "The Application of the Electron Theory to the Radio." Roscoe Nunn, meteorologist of the U. S. Weather Bureau, Baltimore, Maryland, director of the Maryland Climatological Service, and Wilbur A. Nelson, state geologist of Virginia and head of the department of geology of the University of Virginia—both former presidents of the Tennessee Academy of Science—were elected to honorary membership.

THE Wisconsin Academy of Sciences, Arts and Letters held its fifty-sixth annual meeting, in joint session with the Wisconsin Archeological Society, at the State Normal School, Whitewater, Wisconsin, on April 9 and 10.

THREE million dollars of a proposed $20,000,000 fund for research in natural sciences has already been pledged, according to an announcement by Herbert Hoover, secretary of commerce. The fund is being raised under the auspices of the newly organized National Research Endowment of the National Academy of Sciences.

WITH the return of the U. S. Naval Observatory Expedition from Sumatra, where it went to observe the total eclipse of the sun last January, the U. S. National Museum comes into possession of a fine collection of biological material brought to this country from the Dutch East Indies. Lieutenant H. C. Kellers, Medical Corps, U. S. Navy, was detailed to the expedition by the Navy Department to collect for the Smithsonian and the National Museum. In three months, with the cordial cooperation of the Dutch, he collected, roughly, 9,000 specimens of reptiles, birds, insects, crustaceans, mollusks and mammals—living and dead.

THE will of the late E. W. Scripps provides that his estate pay annually to Miami University $15,000 for the maintenance of the Scripps Foundation for the Study of Population established at the university in 1922.

THE late Mrs. Harriet G. Smith has left $5,000,000 for a hospital in Chicago for the treatment of contagious diseases. Arrangements have been made by which the University of Chicago is to provide a site for the building and have the use of the hospital for medical teaching and research.

THE U. S. Bureau of Entomology has received an important addition to its collection at the National Museum. Seventy-seven vials containing coleopterous larvae, most of the material having been reared, were sent by E. Rosenberg, of Copenhagen.

THERE has been founded at the Imperial College of Science and Technology, South Kensington, England, a lectureship in memory of Thomas Henry Huxley, to be given annually for the next five years at the college on May 4, the anniversary of Huxley's birth, on some subject "connected with Huxley's activities." The lectureship has been placed under the control of a committee consisting of nominees of the Royal Linnean, Geological and Zoological Societies, the British Academy, the British Museum (Bloomsbury and South Kensington), the Royal College of Surgeons, the University of London, the London County Council and the Imperial College of Science and Technology. The committee is to decide on the scope of the lectures, and to nominate the lecturer each year. At its first meeting the committee nominated Sir Ray Lankester, who declined the invitation for reasons of health. The committee then nominated Dr. Chalmers Mitchell, secretary of the Zoological Society, who has accepted the invitation and will lecture on "Logic and Law in Biology," on May 4.

ACCORDING to the Japanese correspondent of the *Journal* of the American Medical Association, the opening ceremony of the Korea Imperial University was to be held on April 1. About three weeks before that the following appointments were to be made: Professor Unokichi Hattori, Litt.D., as president, and various professors as deans of faculty in the institution. Appointment of the other professors will be made public after the ceremony at the beginning of April. It is settled that Professor Dr. Kiyoshi Shiga will be a senior professor of the medical college. According to the announcement made by the department of education, another imperial university, including a medical college, will be established in Formosa in April, 1928. It is reported that some professors and instructors will be sent abroad to study medical science.

THE *Electrical World* states that, in view of a disinclination on the part of the house committee on coinage, weights and measures to report out the Britten metric system bill, an alternate proposition has been brought forward in the form of a resolution providing that the Secretary of Commerce "initiate and execute plans whereby metric weights and measures may be brought into common use in commerce and merchandising." A sub-committee named to select from the vast amount of documentary material submitted that portion which could be printed as a part of the *Record* without making it too voluminous has finished its work.

UNIVERSITY AND EDUCATIONAL NOTES

THE following promotions have been made at Yale University: Dr. Harold S. Burr, associate professor of anatomy; Dr. Chester R. Longwell, associate professor of geology; Hubert M. Turner, associate professor of electrical engineering; Dr. Erwin B. Kelsey, assistant professor of chemistry, and Dr. Winthrop M. Phelps, assistant professor of orthopedics.

RECENT appointments to the faculties of the University of Chicago include those of Dr. A. Baird Hastings as professor of physiological chemistry and Dr. Louis Leiter as assistant professor in the department of medicine. Professor Harvey A. Carr has been made chairman of the department of psychology.

R. E. SOMERS has been made head of the department of geology at the University of Pittsburgh. Roswell H. Johnson continues as head of the department of oil and gas production.

DR. SELIG HECHT, research fellow, International Education Board, has been appointed associate professor of biophysics at Columbia University.

DR. H. V. ATKINSON, professor of pharmacology in the University of Texas Medical College, has been appointed associate professor of pharmacology in the Iowa State University Medical College.

DR. R. L. EDWARDS, professor of physics at Park College, has been appointed professor of physics at Miami University, succeeding Dr. J. A. Culler, who retires at the end of this year.

DR. ROBERT L. WEBSTER has been appointed head of the department of zoology at Washington State College and entomologist to the experiment station.

AT Brown University, Dr. Rudolph Ernest Langer, of Dartmouth College, has been appointed assistant professor of mathematics and Dr. Harry Edward Farnsworth, of the University of Maine, assistant professor of physics.

DR. FREDERICK LEET REICHERT, of the Johns Hopkins University, has been appointed associate professor of surgery in the Stanford Medical School beginning with the year 1926–27.

DR. C. L. WITHYCOMBE, lecturer in zoology and entomology at the Imperial College of Tropical Agriculture, Trinidad, is leaving the college at the end of the present session, having been appointed lecturer in entomology at Cambridge University.

THE Egyptian Council of Ministers has appointed Sir E. Cooper Perry director of the Faculty of Medicine for three months from the beginning of October next, with the view of organizing that faculty in the newly established University of Cairo.

DISCUSSION AND CORRESPONDENCE

THE HABITS OF THE GRUNION

A MUCH appreciated form of necromancy practiced in California consists of dipping up a teacup full of sand on the shore about Long Beach, in May, at the time of highest tides. The sand is then spread out in a pan and a teacupful of salt water is poured over it. Shortly after, a large part of the sand springs to life and swims about in the form of very active minute creatures, with transparent bodies and big black eyes. If placed in an aquarium these objects remain alive and vigorous for a week, more or less.

The explanation of this magic lies in the habits of the Grunion (*Leuresthes tenuis*), a slender, silvery fish, four to six inches long, of the family of Silversides (*Atherinidae*) much resembling the common Atlantic species, but differing in the absence of teeth.

In the high tides of spring and early summer the grunion comes ashore in hundreds, ascends to the highest wash of the waves, where the female squeezes herself, tail-first, into the sand, depositing her eggs which are fertilized at once by the male. These eggs lie quiet until the next spring tide, unaffected by sunshine or rain, but ready to leap into life at the next touch of salt water, by a process at once marvelous and instantaneous. Two or three broods are produced in one summer, and each year until the fish is four years old.

The life history of the grunion has been most carefully worked out by Miss Frances N. Clark, of the California State Fisheries Laboratory, at Terminal, California, between San Pedro and Long Beach. The record, an illustrated pamphlet of fifty-five pages (offered as a thesis for the degree of doctor of philosophy at the University of Michigan), is published by the California Fish and Game Commission. It is entitled "The Life History of *Leuresthes tenuis*, an Atherine Fish, with Tide-controlled Spawning Habits." The origin of the name "grunion" I have not been able to trace.

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ADSORPTION MECHANISMS

COLLOID chemists have for some time considered adsorption as being of two kinds—"polar" and "apolar,"[1] or adsorption at "watery points" and at "oily points."[2] The writers believe that a more definite classification of adsorption forces in terms of atomic and molecular structure is both possible and

[1] Freundlich, "The Elements of Colloid Chemistry," translated by Barger (Dutton, New York, 1924); p. 64.

[2] Loeb, "Proteins and the Theory of Colloid Behavior" (McGraw-Hill, New York, 1922); p. 283.

desirable. Such a classification will be attempted in this note.

Let us consider first the sources of affinity (*i.e.*, of attraction for other atoms or groups) in an atom or group of atoms. The most common of these are the following:

(a) An unpaired electron in the valence shell of an atom.

(b) A positive atomic kernel (H, Na, Cu, etc.) not surrounded by electronpairs.

(c) An electro-negative atom, or more specifically a lone electronpair (a pair of electrons not acting as a bond between atoms) in the valence shell of a negative atom.

(d) Double and triple bonds and similar structures (such as three- or four-membered rings) in which one (or more) of the bonding electronpairs is not near the line joining the centers of the two atoms it holds together.

The actual magnitude of the attraction between two structures will of course depend not only on the kind or kinds of affinity regions possessed by each but also on what we might call the "degree of affinity" or the "degree of unsaturation," which will vary widely for different substances. Thus we should expect an "acid" hydrogen atom (class b) to have a greater affinity than a hydrogen atom in a paraffine hydrocarbon for an oxygen atom in another molecule (class c).

Structures of type (a), because of their strong affinity for similar structures, rarely exist at ordinary temperatures.[3] Amorphous carbon and the fresh surfaces of some metals, however, probably constitute exceptions to this generalization. Adsorption by these substances we may assume to be largely of the (ab) (ad) and perhaps (ac) types, according to the nature of the substances adsorbed.

From crystal structure and other evidence,[4] we know that (b) and (c) type structures mutually attract each other, often quite strongly. From organic chemistry there is considerable evidence[5] that two (d) structures attract each other, an addition product (often existing only momentarily) being formed. Attractions of these types—(bc) and (dd)—we might assume to be important in adsorption processes. We might also expect (bd) and perhaps also (cd) adsorption.

Adsorption is very likely often a mixture of the above types. By properly choosing the substances studied, however, it may be possible to study separately the characteristics of the different kinds.

[3] *Cf.*, Lewis, "Valence and the Structure of Atoms and Molecules" (Chemical Catalog Co., New York, 1923); Chapter VI. Huggins, *Phys. Rev.*, March, 1926.

[4] *Cf.*, Huggins, *J. Phys. Chem.*, *26*, 601 (1922).

[5] Huggins, *J. Am. Chem. Soc.*, *44*, 1607 (1922).

The relation between the foregoing method of classification and the division into "polar" and "apolar" adsorption is only partly obvious. (bd) adsorption is certainly "polar," while (dd) adsorption is probably to be identified with "apolar" adsorption. The other types are more difficult to classify. Perhaps it will be better not to try, but rather to frankly admit that adsorption is of more than two kinds.

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JOHN FIELD, 2ND

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WHO DISCOVERED VITAMINES?

WHILE it might be irrelevant for humanity who is the discoverer of vitamines, so long as they became known, nevertheless it is a question of general interest for the public and of personal interest to numerous workers in this field.

While the most important work on this subject was done in the years 1911–1912, it suddenly became known in 1919[1] that Sir Frederick G. Hopkins, of Cambridge University, was credited as its discoverer. The same opinion is shared by certain English, American, French and German investigators, to quote only a recent article by Drummond, Channon and Coward.[2] Attribution of the discovery to Hopkins was particularly surprising to me, as I have worked in the years from 1910 to 1915 in London, chiefly at the Lister Institute, on the same subject and never heard Sir Frederick quoted or regarded as the discoverer of vitamines. It is only since I left England in 1915 that these rumors began slowly to penetrate to me. Unless the English investigators possess in their hands some additional experimental evidence, beyond a lecture by Hopkins (which remained unknown to every worker up to 1919) in 1906 and two experimental papers in 1912, in justice to other pioneer workers in the vitamine field he should not be regarded as their discoverer. In fact, his experimental paper was presented so late (1912) that it exerted a relatively small influence on the development of the whole subject. His paper came many years after the researches of Bunge and his school, Forster and others and even later than the work of Eijkman, Grijns, Stepp, Schaumann and myself, and therefore remained unknown to all these workers.

What are the facts? In 1906 Sir Frederick undertook a series of famous experiments on the importance of certain aminoacids in foods, particularly tryptophane, then recently discovered by him. He apparently noticed then that even on adding tryptophane to tryptophane-deficient diet, the animals im-

[1] Report Medical Research Committee, No. 38, 1919.

[2] *Biochemical Journal*, 19, 1047, 1925.

proved for a while, but died, however, later. He refers vaguely in his New York City lecture to an evidence, which at best must have been very inconclusive at this early period,[3] that some hitherto unknown food elements must be present in a complete dietary. He refers to this in 1906[4] as follows:

> But further no animal can live upon a mixture of pure protein, fat and carbohydrate, and even when the necessary inorganic material is carefully supplied, the animal still can not flourish. The animal body is adjusted to live either upon plant tissue or other animals and these contain countless substances other than the proteins, carbohydrates and fats. Physiological evolution, I believe, has made some of these well nigh as essential as are the basal constituents of diet; lecithin for instance, has been repeatedly shown to have a marked influence upon nutrition, and this just happens to be something familiar, and a substance that happens to have been tried. The field is almost unexplored, only it is certain that there are many minor factors in all diets of which the body takes account. In diseases such as rickets, and particularly scurvy, we have had for long years knowledge of the dietetic factor, but though we know how to benefit these conditions empirically, the real errors in the diet are to this day quite obscure. They are, however, certainly of the kind which comprises these minimal quantitative factors that I am considering. Scurvy and rickets are conditions so severe that they force themselves upon our attention, but many other nutritive errors affect the health of individuals to a degree most important to themselves, and some of them depend upon unsuspected dietetic factors.

If we analyze this statement we must admit that Hopkins showed unusual perspicacity at this early time. On the other hand, he showed no evidence that he knew to what class of substances these mysterious agents could be referred. His mention of lecithin, for instance, makes him attribute a particular rôle to already known substances that has been undoubtedly misleading. If we compare this statement of Hopkins of 1906 with the statement of Bunge of 1891, *viz.*, "Mice can live well under these conditions when receiving suitable foods (milk), but as the above experiments demonstrate that they were unable to live on proteins, fats, carbohydrates, salts and water, it follows that other substances indispensable for nutrition must be present in milk besides casein, fat, lactose and salts," we must admit that Hopkins did not advance the question much since the work of Bunge.

As regards my own rôle in the vitamine field the only claims I can put forward are: (1) the recognition of the existence of several vitamines; (2) the right conception about the importance of vitamines for nutrition; (3) the first chemical study of vitamine B (1911), which unfortunately for the problem has not been improved on yet; (4) general stimulation of researches in this field through expressed ideas, experimental and summarizing work.

We come to the conclusion, therefore, that the discovery of vitamines can not be attributed to a single man. Among the pioneer workers in this field can be named: Bunge, Röhmann, Stepp, Eijkman, Schaumann, Suzuki and others. And the most that one can concede to Hopkins is that he was one of the pioneers. His distinguished services in the field of biochemistry and physiology (discovery of tryptophane, the chemistry of the muscle, the discovery of glutathion) together with his charming personality have made him, even without the title of discoverer of vitamines, one of the leaders in the biochemical world.

CASIMIR FUNK

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[3] *J. Ind. Eng. Chem.*, 14, 64, 1922.

[4] *Analyst*, 31, 395, 1906.

CITATIONS OF SCIENTIFIC LITERATURE

MAY I make a comment and ask a question with reference to the recent notes on citations of scientific literature that have been appearing in SCIENCE?

Furfey (February 26, 1926, pp. 231 f.) makes many excellent comments. To his remarks upon the use of *"op. cit."* I should like to add the comment that, much as uniformity is to be desired, clarity is even more important. There is something to be said for footnotes, since they allow the author to add important but casual information and content where a parenthesis or a parenthetical digression would break the main thought. Where references are to be given in footnotes, then it becomes obvious that they should be immediately available. For an author or editor to insist on uniformity with respect to *"op. cit."* means that often the most careful scrutiny of many preceding pages must be undertaken to find references. Plainly in such a case the reference ought to be repeated. On the other hand, the page which makes numerous references to the same articles should certainly not have the reference repeated upon it. There might be some rule, like a rule to repeat the reference every four pages and to use *"op. cit."* otherwise, but in general it seems to me better to let good judgment prevail over reason, and to decide in Ms. when the precise reference can easily be found and when it will be lost among others. My plea here is against arbitrary uniformity by authors or editors.

My other question concerns the place of the date in a citation. Leffmann's (February 26, 1926, p. 231) and one of Merrill's (November 6, 1925, p. 420) instances place the date separately from the volume and pages. It seems to me to be much better for the date

to appear between the citation of volume and the citation of pages, because the nature of the date-number nearly always distinguishes it from the smaller numbers for volume and for pages, and one does not then have to use bold-face type or ordinarily to print "vol." or "v." I remember, however, once bringing tears into the eyes of a librarian by suggesting that the pages be separated from their volume by the date. It seems so logical to follow this order and to make for so much greater clarity that I can not understand why bibliographical practice is ordinarily against it. Can any of the readers of SCIENCE tell me why the date should not be interpenetrated between volume and pages?

EDWIN G. BORING
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A UNIFORM, clear style for footnote citations is unquestionably desirable and no one is in better position to realize it than the editors of journals receiving contributions from a wide range of authors. These very same journals also have a wide range of readers to whom uniformity and fulness of citation will be a boon.

The danger to be avoided in the systematization of footnotes is over-abbreviation. Certainly, Arabic numerals are preferable to Roman because of the greater ease with which they are read; but when it comes to using cryptic formulas such as PSBA, JAFL, BAMNH, PCAS, AJS, ACM, etc., in referring to publications, it seems that we sacrifice clarity for the sake of saving half a line of type and give many a reader a crossword puzzle instead of a clear citation. Ink and paper are cheap. Why not use enough of both to make footnote citations uniform, clear, unambiguous and understandable to every reader?

E. W. GIFFORD
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RAILROAD PASSES FOR SCIENTIFIC WORK

WITH the development of scientific research, many field investigations are carried on. Since science is poor, it would be desirable to have railroad passes to further this work. This laboratory has made plans to investigate some of the results, on the human organism, of a surgical operation. Such work will have to be done in the field, necessitating travel for which we have no funds.

The Interstate Commerce Commission, which regulates the issuing of railroad passes, provides free transportation to "persons exclusively engaged in charitable or eleemosynary work." It makes no mention of the matter of scientific research. Evidently, scientific research is a question which the Interstate Commerce Commission has not considered. Is scientific research charitable or eleemosynary? Possibly a large part of research might be so called since there is no remuneration paid to college professors carrying on such research as an extra load to teaching. The results of much such research evidently are bestowed gratuitously on succeeding generations.

This laboratory has approached one railroad and they express their willingness to donate a pass if they can be sure that such action will be within the law.

It seems that it would be desirable that this question be considered by men of science and some statement be made to the Interstate Commerce Commission in order that this latter body may take some action.

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SCIENTIFIC BOOKS

Mosquitoes of Surinam—A Study in Neotropical Mosquitoes. By C. BONNE and J. BONNE-WEPSTER. Royal Colonial Institute of Amsterdam, Department of Tropical Hygiene, 1925, 558 pp., 31 pl.

DR. BONNE for a number of years was government bacteriologist of Surinam. He and his talented wife, Mrs. J. Bonne-Wepster, greatly interested in all sanitary matters, conceived the idea as early as 1916 that they would make a careful study of the mosquitoes of that region, and the present fine volume is the result. It took many years in the course of its preparation and a number of years more to secure its publication. They began to correspond with the writers in the summer of 1916 and to send in specimens for identification. Later, in 1919, they came to Washington and spent some time in the National Museum studying the mosquito collections and familiarizing themselves with the methods used in the preparation of the four-volume Monograph of the Mosquitoes of North and Central America and the West Indies, the final parts of which had recently been published by the Carnegie Institution. Although very appreciative of the opportunities given them in Washington and greatly pleased with the result of their work here, their thoroughgoing ideas led them subsequently to visit the British Museum and to make a careful study of the types of neotropical species which had been before Theobald's eyes when he wrote his elaborate Monograph of the Culicidae of the World. They then went to Holland and began the arrangements for the publication of their extensive work. A little later they returned to Surinam and continued observations, but have now gone back to Holland, where Dr. Bonne has been made director of the Laboratory of the Cancer Research Institute in Amsterdam.

The book before us is, fortunately for us, written in English. It is printed admirably in large, well-spaced type. It covers 558 pages and is illustrated by thirty-one plates carrying eighty-three figures. These figures are of hypopygial structures and larval details. The work is practically exclusively of a taxonomic character. It includes full descriptions of all the species found by the Bonnes in Surinam, except certain species of *Culex,* subgenus *Choeroporpa* and also gives short notes on all the other species of tropical America known to them. In spite of its rather strict taxonomic character, there are occasional interesting and important biological notes appended to the descriptions. We wish there had been more of these notes and that the authors had been able to insert a separate chapter on group habits and ecology. Although three pages are given to the habits of the yellow fever mosquito, it would have been extremely interesting had they included absolutely everything about this important species that came to their notice in their years of study in Guiana. Their account of the apparent spread of the species from the coast to the interior is suggestive and may be of significance in the consideration of the question of the original home of yellow fever and the mosquito that carries it.

It is quite possible that from the sub-title of the book a misconception may arise as to its scope. It is in no sense a complete treatise on Neotropical mosquitoes. We think it would have been better if Dr. and Mrs. Bonne had confined themselves to the original title, "Mosquitoes of Surinam." Then the original and painstaking observations on those insects would have appeared without dilution. From the sub-title, "A Study of Neotropical Mosquitoes," one would expect a mention of all the recorded Neotropical forms. The authors surely did not intend this construction, since they had but little first-hand information from regions farther south. It results that there is much compilation, in which the original observations seem lost. Of course the new matter is still there, but it has to be delved for and seems fragmentary. Simply the mosquitoes of Surinam would have been a condensed and very creditable piece of work.

If under a natural misconception from the sub-title we were to consider the work as a compilation of Neotropical mosquitoes, it is very incomplete. To begin with, the authors were apparently frightened at the large number of small *Culex* of the group *Choeroporpa,* and they simply left them out. At least the species might have been listed and the probable synonymy, in the opinion of the authors, pointed out. There are forty-five species recognizably described in this group, of which our authors notice but fourteen. By restriction to the tropics and omission of these recently described, the list would naturally be reduced somewhat; but still the omission may be considered serious. Other omissions are less important, but can be picked up here and there. They serve, however, to diminish the authoritativeness of the work as relating to the whole Neotropical fauna. Especially with the Sabethids, lack of personal acquaintance with the species has led to occasional repetitions, as with *homotina,* treated both as a *Wyeomyia* and a *Goeldia.* The Brazilian species described by Lutz and Peryassú have been omitted, as is stated. We think they should have at least been listed. Some day we shall find out what these species are; but with the specific criteria at present in use the old descriptions are worthless. We do not blame our authors for not going further; but we wish the work had been complete for the Neotropics.

But all this concerns itself with what might have been. We realize that the authors' work was done in Dutch Guiana, and that, as an account of the mosquitoes of Surinam, the work has a very high rank. With the exception of Panama, and excluding the work done in Brazil, we do not know of another tropical American region in which the Culicid fauna has been covered with the intelligence, care and completeness exhibited in this volume.

L. O. HOWARD
HARRISON G. DYAR
WASHINGTON, D. C.

SCIENTIFIC APPARATUS AND LABORATORY METHODS

A SIMPLE METHOD FOR OBSERVATION OF THE LIVING CHICK EMBRYO

DURING the progress of a series of observations[1] by the author on the effects of suffocation on the chick embryo, it became very desirable to know the exact time of the cessation of heart beat. It seemed to us that it should be possible to remove a portion of the shell, cover the egg loosely to reduce evaporation and observe the embryo as often as desired. We first tried removing about a fourth of the entire shell from the top of the egg when it was lying in a horizontal position, placing the egg on a piece of paper, covering it with a beaker or tumbler and placing the whole in the incubator. This method enabled us to observe embryos from their forty-fourth hour of incubation to about their hundred and twentieth hour. Eggs opened before the forty-fourth hour of incubation seldom developed further.

Then it was found that by removing about a square inch of shell from the large end of the egg, together with a little albumen, placing the egg in a vertical position in the neck of a short, wide-mouthed bottle, (simply for support in that position), and covering

[1] Byerly, T. C., 1926, "Studies in Growth. I. Suffocation Effects in the Chick Embryo," *Anat. Rec.* vol. 32.

bottle and egg with a beaker just tall enough to clear the egg, the embryo would develop from the twenty-fourth to the hundred and tenth hour of incubation. The embryo came into view at the edge of the exposed surface very soon after the shell was removed. Mortality was rather high.

Up to this time, we had been unsuccessful in developing normal embryos in eggs from which such an area of shell had been removed prior to incubation. But at this point we found that by retarding evaporation still further by plugging the tumbler or beaker used as a cover loosely with a towel or with cotton it was a very simple matter to observe approximately normal development in the embryo from the unincubated stage to about one hundred five hours incubation. These chicks die at a remarkably uniform age; they do not die from the direct effects of evaporation. The causes of their death are being investigated in these laboratories at present.

This method makes it possible for any undergraduate student to study the first four days of the development of the chick embryo in the same chick, to catch any desired stage for histological study, and that without the mastery of a difficult technique or a supply of expensive apparatus. It is almost superfluous to point out the added ease of experimentation that this technique offers the investigator of the early developmental physiology of the chick embryo.

The materials required are: 1 tumbler, 6″ x 2.5″; 1 straight-side bottle, 3″ x 1.5″, and one small towel. The bottle and tumbler should be washed with 95 per cent. alcohol; further sterilization has so far been unnecessary. The towel should be crumpled and placed beneath the bottle containing the egg and all three inserted into the tumbler until the surface of the egg almost touches the bottom of the tumbler. The assembled apparatus is placed in the incubator and may be removed for observation at will. Frequent dissembling of the apparatus for brief intervals to expedite closer inspection seems to do no harm.

T. C. BYERLY

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SPECIAL ARTICLES

THE ORIGIN OF VACUOLES

DEVELOPMENT of vacuoles in the cytoplasm of plant and animal cells is not uncommon both under experimental and natural conditions. As regards plant cells our own historical approach to the subject may be cited to illustrate the fact.

For many years our students have been instructed to study a vacuolization of the cytoplasm that chromates and dichromates in plasmolyzing concentration produce, *e.g.*, in the epidermal cells of onion bulb scales.[1] Later, a similar frothing of the cytoplasm in various cells was noted to occur with any plasmolytic agent after preliminary action of trivalent cations even in very dilute solution.[2] In sufficiently high concentration, however, even the most innocuous plasmolytes by themselves may cause subsidiary vacuoles to arise in the cytoplasm—a matter of common observation.

It is not only with plasmolyzing agents that this effect is produced, but also with other more readily penetrating substances, *e.g.*, narcotics such as chloroform and ether and by salts after exposure to very low concentrations (1 per cent.) of these. The outer surface and also the interior of the chloroplasts are common situations for the vacuoles to arise when produced in this way, as was observed even by von Mohl.

But without any artificial influence similar vacuoles may form in normal cells. One of us recently demonstrated their constant occurrence in the gametes during the conjugation process in *Spirogyra*[3] and further proved their excretory function as exercised in the taking up of water from the central vacuole and its discharge to the exterior in typical "contractile" fashion. The same author has recently found *Vampyrella* to be comparable in a remarkable degree to the gametes of *Spirogyra*, in that rapid excretion of water takes place by the activity of numerous contractile vacuoles appearing anywhere in the hyaline zone of the body; and that in addition to water, solid excreta are ejected by the simultaneous action of small vacuoles dispersed beneath the entire free surface.

To this is now to be added two principal facts primarily observed by the other writer, but studied by both of us, *viz.*, (1) that the vacuoles produced under the action of a strong plasmolyzing agent are also contractile, and (2) that these vacuoles originate from peculiar bodies already present in the cytoplasm. These bodies, more fully described elsewhere, bear a strong resemblance to the growths of lecithin in water which have long been known as "myelin forms." They are normally of irregular and varying shape and consist of an external lipoid (osmic acid reducing) film which is usually liquid and extensible, enclosing apparently a more aqueous interior which is usually in circulation.

On treatment with a rather concentrated plasmolyzing agent, *e.g.*, 1M or .75M cane sugar, the irregular

[1] Lloyd, F. E., and Scarth, G. W., "An Introductory Course in General Physiology," Montreal, 1921.

[2] Scarth, G. W., "Adhesion of Protoplasm to the Cell Wall and the Agents which cause it," Proc. Roy. Soc. Can. Ser. II, *17*: 137, 1923.

[3] Lloyd, F. E., "Conjugation in Spirogyra," Trans. Roy. Can. Inst. *15*: 129, 1924.

bodies round up into small spheres which soon begin to swell and behave actively as contractile vacuoles. Since a fresh vacuole frequently starts up where one has disappeared it is possible that the evacuated membrane of one condenses to form the primordium of another. There is good reason to believe that sugar in the above concentrations enters the cytoplasm, where, by some process that we do not understand, it is probably concentrated in the contractile vacuoles, the resulting swelling and bursting being explicable simply as osmotic and surface tension phenomena. When, owing probably to high viscosity of the external surface of the protoplasm induced, *e.g.*, by chromates, etc., the vacuoles fail to burst, the cytoplasm becomes thickened into a foamy mass.

There are suggestions in the literature that an origin of vacuoles from similar bodies may be the rule in widely different cell types. For example, the production of secretory vacuoles from the so-called "Golgi apparatus" in cells of the Epididymis as described by Nassonov[4] and Ludford.[5] Now in *Spirogyra* one phase of the polymorphic myelin growths answers every description of the "Golgi apparatus." Mention may also be made of Bensley's account[6] based on a study of fixed materials of the evolution of the central vacuoles in onion roots from a canaliculate system which might well be identical with what we have described in the living cell.

To summarize, in the origin of vacuoles a portion of the living protoplasm which is enclosed in a film of lipoid substance enlarges in volume by the intake of water. At what stage the diluted protoplasmic substance ceases to be alive or whether the central vacuole may be part of the living system thus becomes a question analogous to that of the cell wall. There are grounds, however, for regarding the limiting film as not altogether dependent on the life of the cell for some of its most characteristic behaviors. As regards its growth the resemblances to the physical growths of lecithin is remarkable, and as regards semipermeability the lining of the sap cavity, which gives a similar lipoid reaction, may retain this property long after the cell is dead. This has been known since De Vries's "Plasmolytischen Studien," but we have recently observed extreme examples of the fact. In cells "killed" by iodine with eosin the vacuolar membrane contracted in concentrated glycerine; thereafter for 8 days it underwent slow deplasmolysis retaining its smooth contour, and, for a part of the time, maintaining a high concentration of eosin, indeed much higher than on the outside. Recently we have noted that the tonoplast can retain its smooth contour also after sufficient treatment with osmic acid vapor to flocculate the contents (in part) of the central vacuole.

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4 Nassonov, D., Archiv. fur mik. Anatomie, *100*: 1924.

5 Ludford, R. J., Proc. Roy. Soc. B. *98*: 354, 1925.

6 Bensley, R. R., through Cowdry's "General Cytology," p. 343.

THE TRANSFER OF EXCITED ENERGY FROM OZONE TO HYDROGEN AND NITROGEN

FRANCK and Cario[1] have shown that energy may be transferred from photosensitized mercury atoms to hydrogen at low pressures. The behavior of the excited hydrogen leads these workers to conclude that the active gas is hydrogen atoms. Bonhoffer[2] has made a study of the decomposition of ozone by photosensitized chlorine and bromine to determine a relation between the absorbed radiant energy. Rideal and Norrish[3] have used the photosensitization of ozone decomposition by chlorine in a determination of the kinetics of the reaction between hydrogen and oxygen. Taylor and Marshall[4] give the results of their work on the reaction of hydrogen atoms, produced by excited mercury atoms, with a variety of gases, including nitrogen. The hydrogen and nitrogen used was freed from oxygen. Mixtures of nitrogen with excess hydrogen when illuminated with resonance radiation in the presence of mercury vapor showed little or no change in pressure and the tests with Nessler's reagent at the close of the runs were negative. However, Noyes[5] reports that ammonia is formed in mixtures of hydrogen and nitrogen by transference of excited energy from mercury atoms to the molecules of the above gases. In the report by Noyes we are not informed if special precautions were taken to remove oxygen except in his investigation using mixtures of hydrogen and nitrogen in contact with vapor of boiling mercury. In this case no ammonia was formed when oxygen had been removed from the gas mixture previous to its contact with mercury vapor. Dickinson[6] by using the method of Franck and Cario for making atomic hydrogen has shown that excited hydrogen atoms combine with oxygen at 45° C. This work has been extended by Mitchell,[7] who finds that the rate of the reaction between illuminated hydrogen and oxygen in presence of mercury vapor depends upon the pressure of the oxygen; and also that this reaction is retarded in the presence of argon. In the conclusion, he suggests the possibility that the active hydrogen is not atomic. These investigations described above have been conducted largely at low pres-

1 *Zeit. Physik.*, *12*, 162 (1922).

2 *Zeit. Physik.*, *13*, 94 (1923).

3 *Jr. Chem. Soc.*, *127*, 787 (1925).

4 *Jr. Physical Chem.*, *29*, 1140 (1925).

5 *Jr. Am. Chem. Soc.*, *47*, 1003 (1925).

6 Proc. Nat. Acad. Sci., *10*, 409 (1924).

7 Proc. Nat. Acad. Sci., *11*, 458 (1925).

sures and with the gases in the field of light during the period that the transfer of excitation has occurred.

Marshall and Taylor[8] find that active hydrogen produced by the Wood's method in a high tension discharge at low pressures will react with unilluminated chlorine to form hydrogen chloride. In a further study of this reaction Marshall[9] concludes that more hydrogen chloride is formed than can be accounted for by the number of hydrogen atoms entering the reaction tube. He explains these results by means of a chain mechanism. But Wendt and Landauer[10] show that active hydrogen, other than atomic, is formed in a low pressure high tension discharge. Polyatomic hydrogen in a higher quantum state may be a factor to be considered in accounting for the abnormal results obtained by Marshall.

Results have been obtained by Venkataramaiah[11] which indicate that hydrogen is activated by continuous burning of oxygen in hydrogen. He considers that when the combustion is once initiated by spark discharge the reaction activates the hydrogen. Probably electrons of high kinetic energy capable of ionizing hydrogen are emitted by the reacting molecules. This very interesting work of Venkataramaiah's suggested the investigation the results of which are reported in the present communication.

Since active hydrogen is formed in the combustion of oxygen in hydrogen at the temperature of the flame, we might expect the same reaction to take place, but at a much lower velocity, if the temperature was lowered. But hydrogen and oxygen do not combine very readily at ordinary temperatures without the intervention of a catalyst. The problem was to increase the velocity of combination of hydrogen and oxygen at ordinary temperatures without using a solid catalyzing agent. Pickel[12] reports that ozone reacts with hydrogen appreciable below 100° C; also that the union of active oxygen with hydrogen takes place faster than the reversion of ozone to oxygen. It has long been known that ozone is formed in flames, and it was thought that ozone might play a part in the activation of hydrogen in the flame as described by Venkataramaiah. The active hydrogen produced by corona discharge,[13, 14] by electrolysis,[15, 16] and by the displacement of hydrogen from an acid by a metal,[17] will react with nitrogen with the formation of ammonia. Therefore there seemed to be some probability of catalyzing the reaction of hydrogen with nitrogen by using a high concentration of ozone evolved into a mixture of the two gases.

A solution of sulphuric acid sp. gr. 1,213, at 15°, was electrolyzed, using a current of 6.2 amperes. The drop of potential across the electrodes was nine volts. A piece of platinum foil 5 sq cm in area served as a cathode. The anode was a platinum wire .5 mm in diameter and 31 mm in length.

A stream of hydrogen and nitrogen at atmospheric pressure mixed approximately in a ratio of three to one, respectively, and at a velocity close to eight liters per hour, was led directly down over the anode at which the ozonized oxygen evolved at a very rapid rate. The escaping gas mixture was washed with ammonia free water in an absorption bulb such as described by Duane and Wendt.[18]

The gases and sulphuric acid solution were previously tested with Nessler's reagent and found to be ammonia free. The nitrogen was purified in system used by Mr. A. S. Ellis, who is making a study in this laboratory of current density in relation to percentage of active hydrogen produced at cathodes of various metals.

Runs of fifteen minutes' duration were made, and in every case so much ammonia was found upon Nesslerizing the absorbing liquid that the color was too deep for a quantitative estimate. To obtain the quantity of ammonia formed the absorbing solution was diluted with ammonia free water to a definite volume and an aliquot part taken for the Nesslerization. Tests were made on the absorbing liquid for decomposition products of sulphuric acid but none were found.

Runs were made duplicating conditions of those described, except that no hydrogen was mixed with the nitrogen in the gas stream led down over the anode. In every trial the absorbing liquid was free from ammonia. This seems to indicate that the ozone was transferring its excitation to the hydrogen, which in turn was capable of uniting with nitrogen to form ammonia.

Weigert[19] reports that in the dark there is no appreciable reaction between ozone and hydrogen within an hour. It was thought that diffused light might have some influence upon this reaction between ozone, hydrogen and nitrogen; also we wished to learn if this reaction was accompanied by light phenomena such as are associated with the Strutt active nitrogen. Runs were made for fifteen minutes in the dark under the same conditions as described for mixtures of hy-

[8] *Nature, 112,* 937 (1923).
[9] *Jr. Physical Chem., 29,* 842 (1925).
[10] *Jr. Amer. Chem. Soc., 42,* 930 (1920).
[11] *Jr. Am. Chem. Soc., 45,* 261 (1923).
[12] *Zeit. Inorg. Chem., 38,* 307 (1904).
[13] Wendt and Grubb, *Jr. Amer. Chem. Soc., 42,* 937, (1920).
[14] Anderegg, *Jr. Am. Chem. Soc., 47,* 2429 (1925).
[15] Grubb, *Nature, 111,* 671 (1923).
[16] Venkataramaiah, *Nature, 112,* 57 (1923).
[17] Grubb, SCIENCE, *57,* 696 (1923).
[18] *Phy. Rev., 10,* 116 (1917).
[19] *Zeit. Physik. Chem., 90,* 189, 1915.